INTRODUCTORY TEXT-BOOK

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OF

PHYSICAL GEOGRAPHY

BY THE LATE

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Author of 'Introductory and Advanced Text-Books of Geology,' 'Geology for General Readers,' 'Advanced Text-Book of Physical Geography,' &c.

TENTH EDITION

REVISED AND ENLARGED

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PROFESSOR OF GEOLOGY AND MINERALOGY IN THE
MASON SCIENCE COLLEGE, BIRMINGHAM

WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
MDCCCLXXXI
1881

INTRODUCTORY TEXT-BOOK

OF

PHYSICAL GEOGRAPHY

EXAMINATIONS IN PHYSICAL GEOGRAPHY.

UNDER this Title, and in compliance with frequent requests from Teachers and Students, there have been prepared for these Text-Books (Introductory and Advanced) two sets of Examination, with references, in each case, to the paragraphs of the Text on which the question is founded. Adapted to two grades of proficiency, and arranged, each as far as it goes, so as to present a systematic epitome of Physical Geography, these series of questions enable the Teacher to frame his examinations with greater sequence and connection than his time will ordinarily permit, while to the Student they afford a ready means of testing his own progress and proficiency.

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"If, preserving the etymological sense of the word *Geography*, we should, with many authors, undertake to limit this study to a simple description of the surface of the globe, and of the beings that are found there, we must at once renounce the idea of calling it by the name of *science*, in the exalted sense of this word. To describe without rising to the causes, or descending to the consequences, is no more science than merely and simply to relate a fact of which one has been a witness. The geographer who thus understands his study, seems to make as little of geography as the chronicler of history."—GUYOT'S *Earth and Man.*

PREFACE.

THIS little treatise, like the Author's 'Introductory Text-Book of Geology,' is intended to convey in a simple but systematic manner the leading facts of the science to which it relates. The learner is not troubled with a mass of details which it is impossible for him to remember, nor is he deterred from the study of a most interesting and important branch of knowledge by an array of astronomical, geological, and meteorological data, which, while they bear but distantly on his subject, are altogether unnecessary at this stage of his progress. A great deal of valuable information may be acquired respecting the external conditions of our globe—its lands and waters, their extent and configuration, their climate and vegetable and animal productions—without burdening the mind with unimportant distinctions on the one hand, or going, on the other, into the higher reasonings on which the phenomena of Physical Geography depend. It is the object of this initiatory volume to facilitate the acquisition of such knowledge, and prepare the learner, should he wish to proceed beyond this stage, for the study of the subject in its more exact and extended aspects. It should be remembered, however, that even in its simplest form the science of Physical Geography is by no means a child's study, and that the comprehension of its truths will

be greatly assisted by a previous acquaintance with the elements of General Geography. Under this conviction the Author has endeavoured to produce a *Text* not a *Task* book—a thing to be read and reasoned, and not a compilation of unconnected facts to be irksomely and uselessly committed to memory.

While the text has been prepared on a general plan, and is capable of being studied in connection with any modern set of physical maps, the order has, in most instances, special reference to Keith Johnston's 'School Atlas of Physical Geography,' as yet by far the best and most available of these publications.

EDINBURGH, *December* 1862.

SECOND	EDITION—*Published*		*Dec.*	1864.
THIRD	"	"	*June*	1868.
FOURTH	"	"	*Jan.*	1870.
FIFTH	"	"	*Feb.*	1872.
SIXTH	"	"	*Nov.*	1873.
SEVENTH	"	"	*Nov.*	1874.
EIGHTH	"	"	*Feb.*	1876.
NINTH	"	"	*Oct.*	1878.
TENTH	"	"	*July*	1881.

TENTH EDITION.

In preparing the present edition of this work for the press, I have been guided mainly by a desire to bring up the information it contains to the present date. I have, therefore, made no changes in its original textual arrangement, so that no great inconvenience can be felt in using it for class purposes with any of the later editions. Each numbered paragraph is devoted to the same subject as heretofore; but such corrections and additions have been made throughout as were felt to be necessary in order to give the pupil the full advantage of recent research and speculation. The corrections bear mainly upon the information derived from physics and meteorology. The chief additions include—(1) a summary of those results of the Challenger Expedition which have reference to the depths, deposits, and temperature of the ocean; (2) an account of British storms; (3) a description of the Biological regions of the earth; and (4) a short sketch of Dr Huxley's arrangement of the human family. This additional matter has been illustrated by some new maps. The map of "Ocean Depths" (p. 121) has been copied from the similar map in Dr Wyld's 'Thalassa' (Marcus Ward & Co., Belfast), with the kind permission of the author and publishers.

CHARLES LAPWORTH.

Madras College, St Andrews,
June 1881.

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PHYSICAL GEOGRAPHY.

I.

PHYSICAL GEOGRAPHY AS A SCIENCE.

Its Aim and Objects.

1. GEOGRAPHY (from two Greek words—*ge*, the earth, and *graphé*, a writing or description) embraces, in its widest sense, all that can be known of the superficial aspects of our globe—its lands and waters, their extent and configuration, their altitude and depth, the atmosphere that surrounds them, their varied conditions and climate, and, finally, the distribution of the plants and animals by which they are respectively peopled.

2. A science embracing so wide and varied a subject most naturally presents itself under several heads or departments; and thus we have what is termed *Mathematical Geography*, which devotes itself to the forms, dimensions, motions, and general divisions of the earth as a planet forming part of the solar system; *Political Geography*, which relates to the arbitrary subdivision of the earth into empires, kingdoms, and states, with their populations, manners, religion, laws, industry, commerce, and other features, distinctive of such subdivisions; *Descriptive* or *General Geography*, which restricts itself to an account of the external aspects of the lands and waters—their extent and configuration, their scenery, life, and other obvious features—without inquiring into the causes that produce these appearances; and, lastly, we have *Physical Geography*, which, while it embraces all

the natural conditions of the lands and waters depicted by descriptive geography, proceeds further to inquire into the causes that produce these results, and by which they are in the course of nature continually reproduced within certain limits of change and modification.

3. Physical Geography is thus the highest department, its aim being not only to describe the external aspects of the terraqueous globe (Lat. *terra*, land ; *aqua*, water), but to inquire into those conditions of position, altitude, soil, heat, moisture, and the like, which govern the distribution of plants and animals on the land, and those conditions of depth, composition, and temperature which regulate, in a similar manner, the distribution of plants and animals in the ocean. The Land, its continents and islands, its mountains and valleys, its soil and climate, its scenery and life-arrangements—the Ocean, its seas and bays, its shoals and depths, its composition and temperature, its aspects and life-dispersion,—are the special objects of Physical Geography, and its highest aim is the discovery and expression of those laws which regulate the action and reaction of land, water, and atmosphere in the production of physical phenomena (Gr., appearances in nature). Physical Geography thus rises above the mere description of external appearances, and seeks to explain the causes that produce them—arranging the whole into a system of world-machinery, whose modes of action can be understood, and whose results it is possible to determine.

4. Rising to this conception of his science, and viewing the beautiful and diversified field before him, the student of geography meets a problem in every phenomenon that presents itself, and finds a solution in every incident that occurs. Why, for instance, do two countries lying within the same parallels of latitude present such differences in climate? Why are mountain-heights perpetually enveloped in snow, while the lower ridges are clothed in verdure and blossom? Why is one region of a continent arid and rainless, while another is deluged with periodical torrents? Why do the winds in certain latitudes blow steadily for weeks in one direction, while in another they are fitful and irregular? Why should one expanse of ocean be still and tideless, while another swells and falls with tides, and is traversed by currents? Why should the plants and animals that flourish

in one region dwarf and die out if transferred to another that seems equally fertile in soil and genial in climate? Why should the men at the mountain-foot be tillers of fields and dressers of vineyards, while those a thousand feet higher are herdsmen and shepherds? Or why should one country be the scene of busy industry and successful commerce, of intellectual activity and mental culture, while another as fair, and even more fertile, remains the mere squatting-ground of indolent, dependent, and semi-civilised hordes? These and a thousand similar questions press themselves upon the attention of every geographical observer; and while the facts may be detailed with clearness and accuracy by Descriptive Geography, we must turn to Physical Geography for a rational solution of the phenomena presented—the order in which they occur, and the causes on which they appear to be more immediately dependent.

5. In the prosecution of his subject, the student of Physical Geography appeals to Astronomy for what relates to the figure, size, motions, and other primary conditions of our planet; to Geology for the structure and constitution of the rocky crust, which forms the groundwork of all geographical diversity; to Meteorology for much that belongs to climate and its allied phenomena; while from Chemistry and Physiology he derives important aid in dealing with the nature, growth, and dispersion of plants and animals. Though drawing in this manner from other sciences, it by no means follows that the student should be deeply read in Astronomy, Geology, or Meteorology. All that is necessary is, that he be able to perceive the connection and interbearings of these sciences, and be capable of appreciating the importance of their deductions as far as they relate to his own immediate study of Physical Geography.

Theoretical and Practical Importance.

6. The value of such a science must be obvious to the most casual observer. To determine the relative extent of the land and water that constitute this terraqueous surface —the varying altitudes of the one and the depths of the other, the climates of the one and currents that traverse the other, with the infinitely diversified productions of both—is

not only a source of high intellectual enjoyment and culture, but a task of prime industrial necessity. Scattered over the earth's surface, separated by sea and mountain, enjoying different climates, and placed in proximity to different mineral, vegetable, and animal products, it is a natural necessity that different nations should trade and barter with each other. To ascertain the peculiarities of this varied surface, to learn the variety of its products—to know all, in fine, that relates to the home we tenant, and the comforts and necessaries with which it is furnished, as well as the obstacles or facilities that lie in the way of obtaining them—is the sum and substance of Geography.

7. The observation and reasoning required in geographical research, the amount of information obtained, and the curiosity gratified, by faithful descriptions of distant and diverse regions, constitute, on the one hand, its theoretical value; acquaintance with their mineral, vegetable, and animal products, now so indispensable to civilised existence, the conditions under which these occur, and the capability of the latter for naturalisation in other countries, form, on the other hand, its economical or practical importance. To the navigator dependent on the winds and currents of the ocean; to the pioneer and settler in new lands; to the merchant-traveller in search of additional products; to the gardener and farmer who seek to naturalise the plants and animals of different regions; and even to the physiologist and psychologist who would study the influence of climate and other conditions on health as well as on mental peculiarity,—Physical Geography becomes a science of direct and important utility. Combining, therefore, its theoretical with its practical bearings—the mental discipline with the useful information it imparts—our science has paramount claims alike on the attention of the philosopher, the statesman, the sailor, the farmer, the merchant, and manufacturer.

Hints to the Learner.

8. To present an outline of this science intelligible to beginners, and preparatory to a more exact and extended course of study, is the object of the present treatise; and the learner will best accomplish his purpose who step by

step confirms the statements of the text by reference to the maps of his atlas. By this double process any little difficulty will be more readily mastered, while the facts will be fixed more clearly and permanently on the memory. Every principle thoroughly understood becomes a key to some other problem; hence the value of systematic treatment, and the necessity of a clear comprehension of the successive stages by which the higher problems are attained. The study of General Geography—the positions of towns, courses of rivers, heights of mountains, and the like—is for the most part little better than a task of memory; Physical Geography, on the other hand, requires reasoning at every step, and the student will find his reasonings greatly assisted, not only by the systematic use of his atlas, but by the habit of appealing to the phenomena presented by his own immediate district. There are few localities, however limited, that do not present their alternations of hill and dale, of lake and river, of warm winds and cold winds, of periods of drought and periods of rainfall; of plants that flourish in the marsh and others that thrive only on the thirsty upland; of animals that frequent the plain and others that seek the lofty mountain; and by noting such distinctions, and the causes concerned in their production, the mind will be better prepared for the comprehension of the phenomena of wider and more varied regions.

9. As the botanist, zoologist, and geologist find the objects of their studies in every walk through the fields around them, so the student of Physical Geography will find the illustrations of his science in every locality he may visit. Every district has its own features of highland and lowland, its streams and lakes and rivers, its peculiar winds and rains and frosts, its special arrangements of plants and animals; and he who understands best the governing causes of these local peculiarities will be best able to deal with the general problems of Physical Geography. "Wherever our home is," says Carl Ritter, "there lie all the materials for the study of the entire globe." There is nothing fortuitous in the economy of our planet: every breeze that blows, every cloud that sweeps across the firmament, and every shower that falls—fickle, uncertain, and local as these may appear—are as much the results of law and law-directed forces as the rising and falling of the tides, or the revolu-

tions of the planets. Impressed with this conviction, and seeing how closely every incident in nature is connected with another, the student will consider no occurrence as too trivial, and no fact as too insignificant, to deserve his attention.

RECAPITULATION.

10. In the preceding paragraphs we have endeavoured to show that the object of Physical Geography is to describe the external conditions of the globe, and discover the causes by which they are maintained or modified. It treats of the earth's surface as composed of land and water, determines their extent and configuration, their altitude and depth, the climatic and other conditions that influence the growth and distribution of the plants and animals by which they are respectively peopled; and, rising above these, it endeavours to account for such mental and social peculiarities of different nations as appear to be dependent on external circumstances. Deriving from Astronomy what relates to the figure, dimensions, motions, and other primary features of our planet; from Geology its description of the structure and composition of the rocky crust to which it mainly owes its surface diversity; from Meteorology the explanation of the proximate causes of the variety of climates; and from Chemistry and Physiology their account of the more intimate nature of vegetable and animal life,—Physical Geography proceeds to apply these adjuncts to its own proper field of inquiry, and from the whole deduces a rational and connected account of the cosmical phenomena by which we are surrounded (relating to the world—Gr. *kosmos*, order, arrangement). And the more succinct and sequential our study of these phenomena, the more satisfactory will our knowledge become, not, to be sure, of the whole of nature, for that is too vast and varied for any individual mind to comprehend, but of that department which deals most immediately with the aspects of the terraqueous surface we inhabit-

11. As a science of observation and deduction in connection with the external conditions of this beautiful planet of ours, it possesses high intellectual attractions; and as bearing on its mineral, vegetable, and animal products—their abundance, distribution, and capabilities of dispersion—it becomes to civilised nations a study of prime industrial importance. The more extensive and intimate our knowledge of terraqueous phenomena, the more certain and reliable the deductions of Physical Geography; and, fortunately, this knowledge is yearly on the increase, not only through individual adventure, but through national and systematically directed researches. And rightly so; for the more man knows of the economy of the globe, the more fully can he avail himself of its favours, and the more closely can he direct his operations in conformity with its requirements.

II.

THE EARTH—ITS GENERAL OR PLANETARY RELATIONS.

Figure, Motions, Dimensions.

12. By the general relations of the earth are meant those primary conditions of form, size, density, motion, and the like, which belong to it as a member of the planetary system. From these conditions arise all those multifarious actions and reactions that take place on its surface—the alternations of night and day, heat and cold, summer and winter, growth and decay, the winds and motions of the atmosphere, the tides and currents of the ocean, and in fact everything that confers on it geographical diversity and change. Thus, on its axial rotation depends the recurrence of light and darkness; from its revolution round the sun arises the succession of the seasons, with all their varied effects on vegetable and animal life; from the unequal reception of the sun's heat by the terraqueous surface and atmosphere, result the various phenomena of what we call weather and climate; while from the attraction of the sun and moon, and the earth's own proper motions, spring the flow and ebb of the tides, and the other great currents of the ocean. The consideration of these conditions belongs, no doubt, more especially to Astronomy and Physics; but as much may be here summarised as will enable the student to lay the foundation, as it were, of his own special science.

13. Astronomers have determined that the earth we inhabit is one of a number of planets that revolve at different distances, and with different velocities, round the sun as a common centre—constituting what is termed the *solar system* (Lat. *sol*, the sun). These bodies, some of which are nearer the sun than our earth, and others more remote,

some vastly larger, and others smaller, are nearly all spheroidal in form, and move from west to east, in courses or *orbits* more or less circular. As at present known, this solar system consists of the great centre or *sun;* eight large or primary *planets*—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune; above two hundred ascertained *planetoids*, or small planet-like bodies (generally known as the Asteroids), between the orbits of Mars and Jupiter, and occupying, it is thought, the place of a large primary; twenty secondaries or *satellites*, revolving round their primaries; an unknown number of *comets*, which move round the sun in extremely elliptical orbits, and consequently are seen only at widely distant periods; and several groups of *meteors*, whose orbits are not well defined, and which become visible only by coming in contact with, and by being ignited in, our atmosphere. As the secondary planets revolve round their primaries, and these, again, round the sun, so the solar system itself may revolve round some vaster centre, and this order of things through systems and centres that baffle the grasp of our finite conceptions. The sun itself is about 852,900 miles in diameter, and revolves upon its own axis in a period calculated at 25 days, 0 hours, 17 minutes. The names of the planets, their diameters, distances from the sun, times of revolution and rotation, and number of satellites, are exhibited in the following table:—

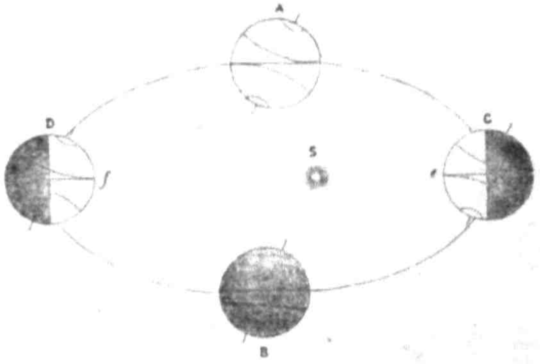
Names and Order of Planets.	Diameters in English Miles.	Distance from Sun in Miles.	Revolution in Days.	Rotation in Days and Hours. D. H. M.	No. of Satellites.
Mercury, . .	3,058	35,392,000	87.969	1 0 5	...
Venus, . .	7,510	66,134,000	224.700	0 23 21	...
Earth, . .	7,926	91,430,000	365.256	1 0 0	1
Mars, . . .	4,363	139,311,000	686.979	1 0 37	2
Asteroids, .	...	250,000,000	2,000,000	...	...
Jupiter, . .	84,846	475,692,000	4,332.584	0 9 55	4
Saturn, . .	70,136	872,137,000	10,759.219	0 10 29	8
Uranus, . .	33,247	1,753,869,000	30,686.820	0 9 30	4
Neptune . .	37,276	2,745,998,000	60,126.720	...	1

14. As stated above, the distance of the Earth from its central orb is 91,430,000 miles—or, in round numbers, ninety-two millions of miles. Its time of revolution round

the sun is about 365¼ days—or, more precisely, 365 days, 6 hours, 9 minutes, and 10 seconds; and this period of revolution we designate *a year*. Besides this annual revolution round the sun, the earth rotates or turns on its own axis in 24 hours—or, more exactly, in 23 hours, 56 minutes, and 4 seconds; and this period of rotation constitutes *a day*. In other words, the earth turns on its own axis three hundred and sixty-five times during the course of a single revolution round the sun; and thus the more frequent and obvious motion of daily rotation has been taken as the unit of measurement for the longer and less apparent motion of annual revolution. In these movements of annual revolution and daily rotation, the earth is attended by a minor or secondary body, which revolves round her as she round the great central luminary of the system. This secondary planet or *satellite* (Lat. *satelles*, an attendant) is the moon, which is 2160 miles in diameter, and which completes her revolution round her parent orb (at a distance of 238,000 miles) in 27 days, 8 hours—or, in round numbers, in 28 days, or one lunar *month* (Lat. *luna*, the moon). These motions, and times of motion, are determined by the controlling influence of the sun as dependent upon the force of gravitation; and it is by the same great force that all the heavenly bodies that lie beyond our system are held in harmonious order.

15. The sun being the great source of light, heat, and other ethereal influences, it necessarily follows that, during the earth's rotation on her axis, only one half of her surface can be exposed at a time to these influences; hence the alternations of *day* and *night*, and all the phenomena that accompany these alternations. But day and night are of unequal and varying lengths at certain localities, according to the *seasons;* and these seasonal successions are caused by the fact that in performing her revolution, the earth's axis is not perpendicular, but inclined or slanting at an angle of 66½ degrees to the plane of her orbit, so that at one period she receives more of the sun in the northern hemisphere, and at another period more in the southern hemisphere; or in other words, the sun seems to pass alternately north and south of the equator. The accompanying diagram will assist in explaining the consequences of this obliquity of axis. Thus, S is the sun, with

the earth represented at four different points in her annual orbit. At A and B the light and heat of the sun strike at the equator or middle line, and consequently day and night are of equal duration. At any intermediate position, day and night are respectively lengthened and shortened: when at C the north pole is in darkness; and when at D the



Succession of the Seasons.

south pole is in the same state. When the point presented to the sun is at *e* (which is on the 22d December), it is midsummer to all the southern parts of the earth, and winter to all the north; but as the exposed part advances towards the point *f*, the northern regions gradually receive more and more heat, till on the 21st of June it becomes their midsummer. Such are the main systemal motions of the earth that regulate our days, years, months, and seasons: let us now advert to her own proper dimensions, as determined by the astronomer and mathematician.

16. The body which thus rotates on its own axis, while it revolves round the sun, and is in turn revolved around by the moon, is not, strictly speaking, a sphere or globe. A diameter taken along its axis, or the ideal line round which it rotates, is only 7899.170 miles, while one taken in the opposite direction is 7925.648 miles. The equatorial diameter thus exceeds the polar by about 26½ miles, thereby causing a deviation from the true globular form, and producing what is termed an *oblate spheroid* (Gr. *sphaira*,

a sphere; *eidos*, form); that is, a figure flattened in the direction of its axis, and bulging out all around somewhat in the shape of an orange. Such a figure can be produced by rapidly spinning a ball of yielding material (like soft clay or putty) round its own axis, when the tendency which all rotating bodies have to fly off from the centre (centrifugal force) causes the mass to bulge out at the circumference, and to flatten in proportion at the ends or *poles* of the axis. To this centrifugal force arising from rotation, and to some original yielding condition of the earth's mass, is its oblate or spheroidal form usually ascribed. The earth's mass, as is well known, is kept together by the force of *gravitation;* and had it remained at rest, its form would have been perfectly spherical; but the moment it began to turn on its own axis, the particles of its mass began to obey another law—viz., that of *centrifugal force*, which exerts itself at right angles to the axis of rotation, and increases in proportion to the rapidity of rotation, and to the square of the distance from that axis. Hence the greater bulging-out of the earth's mass at the equator, where the distance from the axis is greatest; and hence also the gradual declension of centrifugal force as we proceed towards the poles.

17. It has been proved, we have said, by the astronomer and mathematician, that the true figure of the earth is that of an *oblate spheroid*, or ellipsoid of revolution; but of its *general spherical* or *globular form*, the ordinary observer has many evidences, among which may be mentioned the following: 1. As a vessel sails away from the land we first lose sight of her hull, next of her lower or main sails, and lastly of her topsails and pennants, thus clearly showing that she is passing over a spherical surface. 2. The reverse of this also holds true; for the mariner as he approaches the land first sees the mountain-tops, and on gradually nearing it, the lower grounds, stage by stage, make their appearance. 3. Had the earth's surface been flat, it would have been all at once illuminated by the rays of the sun; but being convex or round, each place, as it turns from west to east, has its sunrise, noon, sunset, and night in succession—one half of the globe being thus always in light, while the other is in darkness. 4. In travelling any considerable distance north or south, new stars gradually come into view in

the direction to which the traveller is advancing, while others disappear in the direction from which he is receding. 5. Many navigators, by constantly sailing in one direction, or nearly so, whether due east or due west, have returned to the port from which they set out, thus making what is termed the *circumnavigation* of the globe. 6. The shadow which the earth casts on the moon during an eclipse is always circular. And lastly, the earth belonging to a system or brotherhood, the other members of which are globular, the fair presumption is that she also is of the same form.

18. Calculating from the dimensions given in the preceding paragraphs, the *mean diameter* of the earth will be 7912.409 miles, and its *mean circumference* or girth, 24,858 miles. It is usual, however, to speak, in round numbers, of the diameter being 8000, the radius or distance from the surface to the centre as 4000, and the circumference as 25,000 miles. The superficial area of a globe of these dimensions amounts to 197 millions of square miles; and of these about 51 millions consist of land, and 146 millions are occupied by water. The proportion of land to that of water may therefore be said to be, in round numbers, as *one* to *three*; or in other words, while one-fourth of the earth's surface consists of dry land, the other three-fourths are covered by the waters of the ocean. The solid contents of the mass have in like manner been computed to exceed 260 thousand millions of cubic miles—an amount which, though expressible in figures, is altogether beyond the grasp of human conception. It is enough, then, for the learner to be convinced of the magnitude of these amounts, without troubling himself with the remembrance of their numerical expressions.

Density, Temperature, Atmosphere.

19. The density of the globe, as compared with the materials at its surface, has been determined with considerable precision. The average or mean density of the most prevalent rocks is about 2½ times that of water; while the density of the whole mass, as determined by most careful experiment, is 5½ times (5.675) that of water. It is evident from this that the interior of the earth cannot

be composed of the same materials that constitute its outer portion; for these, under the law of gravitation, would be so compressed at the depth of a few miles as to give a greater mean density to the whole mass than the ascertained facts will allow. Thus, it has been calculated that water, at the depth of 362 miles, would be as dense as quicksilver; and that the density of marble, at the centre of the earth, would be 119 times greater than what it is at the surface. Either, then, the interior of the earth is composed of materials differing altogether in nature from those known at its surface, or the compression of gravitation must be counteracted by some highly expansive force, such as heat, so as to maintain the mean density which scientific men have already determined. It is thus that geologists and geographers, adopting the language of geologists, speak of the "crust of the globe," and of the "interior of the globe;" meaning by the former that outer portion composed of rocks and rock-masses which can be observed and examined—and by the latter, that inner portion which is placed beyond such investigation, and respecting the nature of which we can offer little more than conjecture.

20. Closely connected with the density of the globe is its temperature, or the amount of heat that pervades it. As one of the orbs of the solar system, the earth has a variable superficial or atmospheric temperature; it has also a temperature peculiar to the rocky crust; and judging from volcanic action, there is also a high and more remarkable interior temperature. Respecting the *superficial temperature*, which constitutes the great theme of Climatology, to be noticed hereafter, it may be stated in the meantime, that it is influenced from day to day, and from season to season, by the heat of the sun; that it varies according to the latitude, being greatest at the equator and gradually decreasing towards the poles; that it is greatly modified by the extent and distribution of sea and land—the sea and sea-coasts being more equable than inland continents, which experience extremes of heat in summer and extremes of cold during winter; that it is also modified by the absorbent or radiating nature of the soil, according as this may be dark or light coloured, dry or moist, porous or compact; and, lastly, that it is notably affected by elevation above the mean level of the sea, the higher being the colder regions.

21. The *temperature of the accessible crust*, on the other hand, is affected either by the direct heat of the sun, by heat generated chemically among its own materials, or by heat derived by conduction from the interior. During summer, for instance, the earth is warmed to a certain depth by the heat of the sun; during winter this heat is given off to the surrounding atmosphere; and though the heat of one summer and the cold of one winter may differ from the heat and cold of others, still, on an average of seasons, the results are pretty equable. It may therefore be stated in general terms, that in summer the crust of the earth at small depths is cooler than at the surface; that during winter the crust at these depths is warmer than at the surface: but that, at the depth of 80 or 90 feet, the variations of summer and winter become wholly insensible; hence the so-called "stratum of invariable temperature." As to the amount of heat generated within the crust by chemical and magnetic forces we have no real knowledge; but to such forces, as well as to conduction from the interior, may be safely ascribed the higher temperature experienced in mines, wells, and other deep-seated excavations.

22. Respecting the *heat of the interior*, we see it abundantly manifested in hot springs, volcanoes, and the like; and have, by direct experiment, been enabled to arrive at some important facts relative to its descending rate of increase. Thus it has been found by experiments in coal-pits, Artesian wells, and metalliferous mines, that after passing the depth at which the surface-heat becomes inappreciable, the temperature begins to rise, and this more or less steadily for every fathom of subsequent descent. This descending temperature, though not alike in all mines and borings, may be taken at an average of 1° Fahrenheit's thermometer for every 60 feet of depth; and calculating at this increase, a temperature (2400° Fahr.) would be reached at a depth of 25 miles or thereby, sufficient to keep in fusion such rocks as basalt, greenstone, and granite. These facts have led some to argue that the highly-heated interior of the globe is in a state of perfect fusion, and is surrounded on all sides by a comparatively thin film of solid crust, as the liquid interior of an egg is surrounded by its thin stony shell. By others it is contended that the

enormous pressures which must exist at great depths prevent the complete fusion of the materials of the interior, and that the earth is practically solid to its centre. But intense as the interior heat may be, and active as it undoubtedly is in the production of volcanic phenomena, the surface temperature of the globe is scarcely if at all affected by it (according to Fourier, only $\frac{1}{17}$ of a degree), owing to the weak conducting properties of the rocky crust.

23. Besides these original conditions of form, size, motions, density, and temperature, there is also that of its *atmosphere*, or aerial envelope which surrounds it on every side, and becomes an integral and indispensable portion of its constitution. This atmosphere, as is well known, is mainly composed of two gases—nitrogen and oxygen—79 parts of the former to 21 of the latter, with a small percentage of carbonic acid; other ingredients being regarded as extraneous impurities. As at present constituted, the air is indispensable to vegetable and animal life; both alike breathe it, and by this breathing the functions of vitality in both are alike sustained. Being an elastic or compressible medium, the air nearest the sea-level is denser than that at considerable elevations; and by calculating the rate at which this rarity takes place, it has been estimated that at the height of 50 miles above the sea, the atmosphere becomes so rare or light as to be all but inappreciable. We have thus surrounding the earth, and partaking in all its movements, a gaseous envelope or atmosphere, whose pressure at the sea-level is estimated at 14¾ lb. avoirdupois on every square inch of surface, but which gradually becomes lighter and lighter or more attenuated as we ascend, till at the height of 50 or 60 miles its effects as a medium of refraction and transmission are all but inappreciable—and yet not *inappreciable*, for meteors are ignited by their frictional passage through it at the height of 90 or 100 miles. Through this envelope (whatever its absolute thickness or height may be—see Chap. XI.), the heat and light of the sun are equally diffused and modified; it is also the recipient and diffuser of all watery vapours arising from the earth; and from local alterations in its density or expansibility, caused by heat and the like, arise all aerial currents or winds, whether steady and regular, or fitful and irregular. The atmosphere is thus the great medium through which

light, heat, moisture, and other vital influences are communicated to the plants and animals that adorn the earth's surface; it is also the great laboratory in which all meteorological and electrical phenomena are elaborated; and hence all the varied aspects and results of winds, clouds, rains, snow, hail, thunderstorms, and the like, that constitute the essentials of climatic diversity.

Technical Subdivisions—Points, Circles, Zones.

24. In treating of the earth thus constituted and surrounded, geographers make use of certain terms and technicalities expressive of distance, position, and the like, on its surface, and with these it will be necessary for the learner at this stage to render himself familiar. Thus, the direction from which the earth moves in its daily rotation is called the *West;* that towards which it moves, the *East;* the point to which a spectator looks, with the east on his right hand and the west on his left, is called the *North;* and that behind him, the *South*. In this rotation from west to east, any point on the earth's surface turns towards the sun in the morning, and away from him after mid-day, and thus the terms *Sunrise* and *Sunset* (the sun being a stationary centre) express not real but apparent phenomena. The imaginary line on which the earth rotates is termed its *axis*, and the terminations of this axis its *poles*—that towards the north being known as the *North Pole*, and that towards the south as the *South Pole*. From an idea of the earlier geographers, who were inhabitants of the northern hemisphere, that the north pole was uppermost (though in reality there can be neither upper nor under in a globe freely rotating in space), it is customary in our maps and charts to place the northern part at the top and the southern at the bottom, with the east on the right hand and west on the left. A line distant alike from either pole, and dividing the earth into two equal portions (Lat. *æquus*, equal), is called the *Equator;* the northern being known as the *Northern Hemisphere*, and the southern as the *Southern Hemisphere*. In the same way we may speak of the *Eastern Hemisphere* and *Western Hemisphere*, by supposing the globe divided by a line passing through the poles, and thus necessarily

cutting the equator at right angles. Reckoning London as a fixed point on such a line, Europe, Asia, and Africa will lie in the eastern hemisphere, and North and South America in the western. (See Map, page 49.)

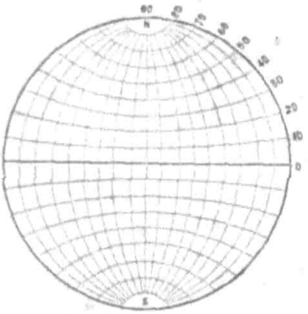
25. Like other circles, the circumference of the earth is divisible into 360 equal parts or *degrees*, and in this case each degree will equal about 69½ British statute miles. At the distance of 23½ degrees north and south of the equator (as shown in the accompanying diagram) are two parallel lines called the *Tropics* (Gr. *tropé*, a turning), from their marking the turning-points of the sun in the ecliptic; that on the north being known as the *Tropic of Cancer*, and that on the south the *Tropic of Capricorn*, because these constellations occupy a corresponding point in the heavens. At the same distance (23½ degrees) from either pole is a parallel line — that on the north being called the *Arctic Circle* (from the northern constellation, *Arctos*, the Bear), and that on the south the *Antarctic Circle*, because opposite (Gr. *anti*, opposite) to that of the north. The space or belt between the tropics is called the *Torrid Zone*, because the sun being always vertical in some part of that space, produces a greater degree of heat than in regions where his rays strike more obliquely. The spaces between the tropics and the arctic and antarctic circles, on either side, are termed the *Temperate Zones* (north and south); and those between these circles and their respective poles, the *Frigid Zones*. It is customary for the botanist and zoologist to subdivide these zones more minutely into equatorial, tropical, sub-tropical, warm-temperate, cold-temperate, sub-arctic, arctic, and polar; but of these subdivisions and their characteristics when we come to treat of the distribution of vegetable and animal life in Chap. XII.

Zones and Circles.

26. The equator has been described as a circle exactly between the poles, and cutting the globe into two equal portions: a line which cuts the equator obliquely (at an angle of 23½°), and touching upon opposite sides of the tropics, is called the *Ecliptic* (Gr. *ekleipsis*, an eclipse). The ecliptic of the heavens is the great circle described by the sun on his apparent annual journey round the earth, and is so named from the circumstance that eclipses can happen only when the moon is in the plane of this circle or very near it. The points where the ecliptic cuts the celestial equator are called the *equinoctial points* or *nodes*, because when the sun is in these parts of his course, the day and night are of equal duration (Lat. *æquus*, equal; *nox*, *noctis*, night). These equinoxes take place twice a year — namely, on the 21st March and 21st September. The ecliptic drawn upon our globes and maps of the world merely indicates the angle which the plane of the celestial ecliptic makes with that of the earth's equator. The term *Greater Circles* is sometimes applied to the terrestrial equator and ecliptic, because they encircle the earth at its thickest part—that is, cut it at planes passing through the centre; and that of *Lesser Circles* to the tropics, arctic, and other circles above described. Besides these circles, another set of lines drawn from pole to pole over the earth's surface, and cutting the equator at right angles, are termed *Meridians* (Lat. *meridies*, mid-day), because when any of these lines is opposite to the sun, it is mid-day or 12 o'clock with all the places situated along that meridian on the same side of the globe; while on the other side it is midnight. When it is noon, for instance, in any particular part of Britain, it is midnight at an opposite and corresponding part near New Zealand; and so on for the intermediate hours at directly opposite parts along the same meridian. Parts diametrically opposite upon the globe are said to be the *Antipodes* of each other (Gr. *anti*, opposite, and *pous*, *podos*, foot), because the feet of their inhabitants are placed, as it were, in opposition to each other.

27. The position of a place on the earth's surface is determined by what is termed its *latitude* and *longitude*,—terms which arose from a notion of the ancients that the earth was longer from east to west than from north to south —or, in other words, had length (Lat. *longitudo*) and breadth

(*latitudo*). The latitude of a place is, therefore, its distance north or south from the equator; hence we speak of north latitude (N. lat.) in the northern hemisphere, and of south latitude (S. lat.) in the southern hemisphere. Longitude, on the other hand, is measured east and west of any fixed meridian—different countries adopting different meridians (usually that of their capitals), Britain that of the Royal Observatory at Greenwich; hence English geographers speak of east longitude (E. long.) and west longitude (W. long.), according as a place may be situated eastward or westward of the meridian of Greenwich. The circles on the earth being divided into 360 degrees, and each degree, again, into 60 minutes, each minute into 60 seconds, and so on, the position of a place can be indicated with great precision; and, for the sake of brevity, certain signs are employed, as 4° 6′ 12″,—meaning thereby 4 degrees, 6 minutes, and 12 seconds. The distance between the equator and either pole being only the fourth part of the earth's circumference, *the latitude of a place* north or south of the equator can never exceed the fourth part of 360, or 90 degrees. Longitude, on the other hand, being measured east and west of a fixed meridian, embraces a whole hemisphere, or 180 degrees; and as the meridians all converge towards the poles, the degrees of longitude become less and less as we approach these extremities. In the latitude of London (51½°) the length of a degree of longitude is 43½ British statute miles, while at the latitude of 60° it decreases to 34½ statute miles. The lines of latitude being necessarily parallel to each other, geographers speak of *parallels of latitudes*—designating those that lie near to the equator as *low* latitudes, those that approach the poles as *high* latitudes, and those that intervene as *middle* latitudes.



Parallels and Meridians.

RECAPITULATION.

28. In the foregoing chapter we have noticed those primary conditions of form, motion, size, density, temperature, and the like, which belong to the earth as a member of the solar system. Those conditions lie, as it were, at the foundation of all change and diversity on the earth's surface—day and night, heat and cold, summer and winter, meteorological fluctuation and climate, oceanic tides and currents, geological waste and reconstruction. They lie, in fine, at the source of all that confers diversity on land and water, and consequently on vegetable and animal life, being directly or remotely dependent on the original constitution of the globe, and its connection with the solar system. It is necessary, then, that the student should render himself familiar with the planetary relations of the earth—its spheroidal form, its daily and annual revolutions, its density, temperature, magnitude, and admeasurements, as well as with those terms and technicalities by which its several portions and positions are known and described.

29. As an oblate spheroid, then, the earth has an equatorial diameter of 7925.648, and a polar diameter of 7899.170 miles; rotates on its own axis in 23 hours, 56 minutes, and 4 seconds, or in one *day*; revolves round the sun in an elliptical path or orbit in 365 days, 6 hours, 9 minutes, 10 seconds, or one *year*; and is in turn attended by the moon, which performs her revolution in 27 days, 8 hours, or one lunar *month*. As the mean circumference of the earth is 24,858 miles, and as she rotates on her axis once in 24 hours, it is clear that any spot on the equator must be borne round at the rate of more that 1000 miles an hour. With every successive removal from the equator, however, the circles of latitude become smaller and smaller, and as they are all carried round within the same period of

24 hours, their rate of motion must be proportionally less. At the 60th parallel, for example, the motion is only 500 miles an hour, and at the absolute poles it ceases to exist. From the obliquity of the earth's axis in her annual course round the sun, the *seasons* differ in the northern and southern hemispheres as follows:—

Season.	*Northern.*	*Southern.*
Spring	March April May	September October November
Summer	June July August	December January February
Autumn	September October November	March April May
Winter	December January February	June July August

30. The mean density of the rocks known at the surface of the earth is about $2\frac{1}{2}$ times that of water, while that of the entire mass is $5\frac{1}{2}$, thereby showing that the interior consists of different materials, or of materials in a different condition, from those in its rocky crust. The earth's internal temperature, as distinct from the climatic temperature received from the sun, increases according to the depth; and this increasing temperature, though little affecting the surface, seems sufficient to keep the interior in a state of fusion, and to be the cause of volcanoes, hot springs, and other thermal phenomena. The earth, besides her own proper mass, is also surrounded by an aerial envelope or atmosphere, consisting in the main of 79 parts nitrogen and 21 oxygen, with a fractional percentage of carbonic acid; and this gaseous envelope, being an elastic medium, is denser at the earth's surface (where it presses with a weight of $14\frac{3}{4}$ lb. on the square inch), and becomes rarer and rarer as we ascend in space, till at the height of 50 or 60 miles its presence becomes all but inappreciable. This

atmosphere is the medium through which the sun's light and heat are equally diffused; the laboratory in which all meteorological phenomena—winds, rains, clouds, storms, &c. — are elaborated; and, in fine, the source whose varied mutations are the proximate causes of all climatic diversity.

31. *In treating of the earth*, various terms and technicalities are necessarily employed by geographers, and with these the learner should early render himself familiar. Thus, the imaginary line on which the earth turns in her daily rotation is termed the *axis*; the extremities of this axis, north and south, the *poles*; the circle between the poles which cuts the globe into two equal portions, the *equator*; these two equal portions are termed *hemispheres* or half-spheres; and the varying belts of surface temperature as we proceed northward and southward from the equator, where the sun's heat is greatest, are respectively known as the *torrid*, *temperate*, and *frigid zones*. The *ecliptic* indicates the apparent path of the sun round the earth; *meridians* are those lines drawn from pole to pole over the earth's surface, and at right angles to the equator, along which the sun is vertical at its highest daily ascension, or *noon*; *latitude*, the distance of any place, measured in degrees, south or north of the equator; and *longitude*, the distance of the same place east or west from any arbitrary or convenient meridian,—that in Britain being the meridian of Greenwich—that in France, Paris—and that in Germany, the island of Ferro in the Atlantic, which has this advantage, that it places every part of the mainland of the Old World within the Eastern Hemisphere.

III.

THE EARTH—ITS INDIVIDUAL STRUCTURE AND COMPOSITION.

The Rocky Crust—Its Constitution and Formation.

32. HAVING considered, in the preceding chapter, some of the more obvious relations of the globe as a member of the solar system, and the terms usually employed to express their connection, we now proceed to describe the leading features of its own individual structure. As the knowledge of its general relations was derived chiefly from Astronomy, so a knowledge of its individual structure is mainly obtained from the teachings of Geology. As the one set of facts could be taught without going deeply into the problems of the astronomer, so the other may be understood without entering largely into the reasonings of the geologist. What, for instance, is the nature of the earth's rocky crust? How are its rocks arranged, and how does this arrangement affect its superficial character? What has stretched out the level plain and upheaved the rugged mountain? What renders one soil obnoxious and sterile, and another genial and fertile? And as the earth's crust is continually undergoing modification under the operation of external and internal forces, what are the effects of such modifications on the general geography of the globe? These and similar problems Geology endeavours to solve, and, with a little explanation, these solutions may be rendered intelligible to the student of Physical Geography.

33. Geologists speak of the "crust of the globe" just as the housewife talks of the "crust" of her loaf. The crust of the loaf is one thing, the inside of it another. The crust or exterior portion of the earth, composed of rocks and

rock-materials that can be seen and handled, is one thing —the interior, of which we can know nothing by direct observation, may be, and in all likelihood is, a very different thing. By observation and comparison we can determine a great many truths respecting the structure and composition of the former; respecting the latter we can offer at best little more than conjecture. The outer portion, or rocky crust, is the great theatre of all geographical phenomena—the foundation of the land and waters—the arena of climatic influences—the field of vital development—and, as such, it behoves the geographer to know something of its history and constitution.

34. On the most cursory inspection of quarries, railway-cuttings, sea-cliffs, and ravines, the observer will find a great portion of the rocks arranged in layers, or lying one above another in beds or strata (Lat. *stratum*, spread out). These are said to be *stratified*, and generally consist of sandstones, clays, shales, or consolidated muds, limestones, and other similar rocks. He will also find another set not spread out in layers, but rising hard and massive in no determinate arrangement. These are termed the *unstratified*, and consist of such rocks as the granites, greenstones, basalts, and lavas. How, he will naturally inquire, have two sets of

A A A, Stratified; B B, Unstratified Rocks.

rocks, so dissimilar in character and arrangement, been produced? and as we can only interpret nature's productions by a knowledge of nature's operations, we must seek for the answer to this question in what is now taking place around us. And first, if we turn to any lake, estuary, or bay of the ocean, we will find that the mud, sand, and gravel carried down by the rivers, or washed from the cliffs by the waves and tides, are deposited and arranged along the bottom of these receptacles in layers or strata more or less horizontal, and in course of ages, one above another, precisely like the shales and sandstones of the quarries and sea-cliffs. Here, then, we are entitled to infer that rocks arranged in layers or strata have been formed through and by the agency of water (Lat. *aqua*)—that is, have been

deposited as sediment (Lat. *sedere*, to settle down) in water, or brought together and assorted by the action of moving water; hence they are termed *aqueous*, *sedimentary*, or *stratified*. If we turn, in the next place, to the volcano or burning mountain, we find that lava and other molten rock-matters are discharged from its crater; and these, when cooled and consolidated, age after age, form mountain-masses, and fill up chasms and rents among the beds they displace, precisely as the granites and greenstones and basalts do among the stratified rocks with which they are associated. Here, again, we are entitled to infer that greenstones, basalts, and other similar rocks, are the products of fire (Lat. *ignis*, fire); hence they are designated *igneous*, *eruptive*, or *unstratified*.

35. In the crust of the earth, then, we have two main sets of rocks, the stratified and the unstratified—the one formed through and by the agency of water, the other through and by the agency of fire. The former are chiefly the products of aqueous and atmospheric waste, the latter the products of igneous reconstruction; and between these two forces, the aqueous and igneous, the crust of the earth has ever been held in habitable equilibrium. Were the aqueous and atmospheric forces to operate uncontrolled, all the higher portions of the dry land would in the course of ages be worn down, and the whole reduced to a dreary uniformity of level; but to prevent such a contingency, the volcanic forces are perpetually exerting themselves from below, and once more upheaving the crust into dry land and diversity of surface. The great design of creation seems clearly to be diversity in time as well as diversity in space, whether under the open air or under the waters of the ocean. Hill and dale, level plain and rugged mountain, are ever attended by diversity of soil, diversity of winds and clouds, heat and cold, and all the other climatic influences on which diversity of plant-life and diversity of animal life are so intimately dependent. To the primary geological oscillations of the earth's crust—its submergences and upheavals, its volcanic outbursts and earthquake convulsions, the wearing away of its softer rocks and the resistance and standing up of its harder—are we therefore indebted for all that confers on its surface geographical variety and diversity.

Relative Age and Arrangement of Rock-Formations.

36. If, then, the crust of the globe be in a state of oscillation between the aqueous and atmospheric forces that waste and wear from without, and the igneous forces that reconstruct and upheave from within—if cliffs and hills are worn down, and lakes and estuaries filled up and converted into alluvial plains—if plains are thrown up into mountains and the sea-bed into dry land—if large tracts of the earth are gradually raised higher and higher above the ocean while other regions are gradually submerged,—it is clear that different portions of the rocky crust must be of different ages and composed of different materials. The present distribution of sea and land has undergone many noted modifications, even within the historic era; and if such changes have been accomplished within a period so brief as a few thousand years, what may we believe to have taken place during the thousands of ages that preceded human history? So numerous have been these changes, as clearly shown by geology, that every portion of the existing land has been repeatedly beneath the waters; and that which now constitutes the bed of the ocean has, probably, been the dry land of former epochs. The record of these changes lies in the stratified rocks, each period producing its own sedimentary deposits, and these deposits constituting what geologists term a *formation*, as having been formed at a certain period, and under the peculiar conditions of that period, in some lake, estuary, or sea.

37. Further, as the sediment of existing lakes and estuaries and seas embed the remains of plants and animals that have lived in these areas, or have been drifted from the land—leaves, branches, trunks, bones, teeth, shells, and crusts; so the sediments of former ages contain the remains of plants and animals that then existed, these remains being petrified or converted into stone (Lat. *petra*, stone; *fieri*, to become). These petrifactions, or *fossils* (Lat. *fossus*, dug up), as they are termed, differ widely in many instances from the plants and animals now peopling the globe; and this difference may be said to increase with the depth and age of the strata that contain them. As a general rule, the

older strata will be the deeper seated; the harder and more crystalline will lie below the recent and superficial; and the older the strata the greater will be the difference between their fossil plants and animals and the plants and animals now existing. Founding on principles such as these, geologists have arranged the stratified rocks into formations and systems according *to their relative antiquities*—each division representing (as nearly as can be determined) a different arrangement of sea and land, and a different aspect of vegetable and animal life during the period of its deposition. Thus, beginning at the recent and superficial, which contain only existing forms of life, and descending through systems whose fossils belong chiefly to extinct races, we have:—

Systems.	*Periods.*
1. POST-TERTIARY, or RECENT ACCUMULATIONS, 2. TERTIARY SYSTEM, or PLIOCENE, MIOCENE, and EOCENE,	CAINOZOIC (*Recent Life*).
3. CRETACEOUS, or CHALK SYSTEM, 4. JURASSIC, or OOLITIC and LIASSIC SYSTEM, 5. TRIASSIC, or UPPER NEW RED SANDSTONE,	MESOZOIC (*Middle Life*).
6. PERMIAN, or LOWER NEW RED SANDSTONE, 7. CARBONIFEROUS SYSTEM, 8. DEVONIAN, or OLD RED SANDSTONE, 9. UPPER SILURIAN SYSTEM, 10. LOWER SILURIAN or ORDOVIAN SYSTEM, 11. CAMBRIAN SYSTEM,	PALÆOZOIC (*Ancient Life*).
12. ARCHÆAN, PRE-CAMBRIAN, or METAMORPHIC SYSTEMS (LAURENTIAN, &c.),	EOZOIC (*Dawn of Life*).

Or, arranging them in diagrammatic form, one above another, as they occur in the British Islands, we have the intelligible sequence represented on page 40.

38. As the stratified rocks have been arranged in chronological sequence, so also the unstratified or igneous admit of a similar though less precise arrangement. As at present, so during every former epoch of the earth's history, the volcanic forces (Lat. *Vulcanus*, the spirit or principle of fire) have been in a state of activity—breaking up the stratified crust, throwing out lava and other products in the formation of hills, and filling up earthquake-fissures with molten rock-matter from below. In course of the earth's mutations,

these earlier products become submerged beneath the waters of the ocean and overlaid by newer sedimentary deposits, again to be broken through by another set of igneous operations, and this consecutively and continuously from the most distant ages up to the present day. As a general rule, the earlier igneous rocks will be associated with the earlier stratified deposits, and the older and deeper-seated will be more uniform and crystalline in texture than the newer and more superficial. Founding on principles such as these, geologists usually arrange the igneous or unstratified rocks in the following chronological order :—

1. Volcanic, associated chiefly with tertiary and upper secondary strata.
2. Trappean, associated chiefly with secondary and upper primary strata.
3. Granitic, associated chiefly with primary and metamorphic strata.

39. The consideration of these systems and subdivisions form the special subject of Geology; but as each formation occupies a distinct portion of the earth's crust, consists of different kinds of rocks, and presents different soils and surfaces, the following summary may be of use to the student of geography: The *Post-Tertiary* consists for the most part of sands, gravels, peat-mosses, coral-growths, alluvial silts, and other superficial accumulations that have been recently formed, or are still in the course of formation. From the nature of their formation, they occupy the flats or lower portions of plains, river-valleys, deltas, and the sea-shores, and as a consequence present little variety of surface or scenery. The *Tertiary System* consists, in most areas, of stratified clays, sands, gravels, marls, and occasional limestones which occupy in general plains and lowland basins, and are rarely elevated into hills of any magnitude. Subjected to the long-continued influences of elevation and atmospheric waste, the system presents greater variety of surface than the post-tertiary; and the districts round London, or the "London Basin," as it is termed, the "Hampshire Basin," and "Paris Basin," may be taken as average types of its scenery. The *Cretaceous System* is composed of sands and sandstones, clays, shales, and notably, in many areas, of thick beds of chalk or earthy limestone. Subjected to atmospheric and other waste, this group is often worn into rounded hills and gently sloping valleys, as is typically illustrated by the "downs" and "coombs" of the

CHRONOLOGICAL SUCCESSION OF BRITISH STRATIFIED SYSTEMS.

south-eastern counties of England. The *Oolitic System*, as developed in Europe, consists of clays, shales, sandstones, and limestones; the calcareous members in general predominating. From the harder nature of the calcareous strata, they have resisted the effects of external waste better than the softer clays and shales; hence the undulating and pleasing character of much of the oolitic landscape as exhibited in the midland counties of England. The *New Red Sandstone*, which comprises the *Triassic* and *Permian Groups*, consists, as its name imports, chiefly of sandstones, sandy marls, and limestones. The sandstones and marls, being of a soft and disintegrating nature, have largely yielded to external influences; hence much of that red tenacious clay and moist pasture-land (Cheshire, &c.) which characterises so large a portion of New Red Sandstone districts. The *Carboniferous System*—so called from its yielding in Britain our main supply of coal—is composed of sandstones, shales, fire-clays, ironstones, limestones, and coals; and, unless where cut through by hills of greenstone and basalt, is generally overlaid by thick tenacious clays (the results of its own weathering and disintegration), which

confer on its landscape a cold, moorland, and uninviting appearance. The *Old Red Sandstone* of Scotland consists mainly of reddish-coloured sandstones and conglomerates, frequently interbedded with or penetrated by sheets and bosses of hard trappean rocks. The easily eroded sandstones have been cut through by deep ravines and broad valleys, while the associated and less tractable igneous rocks rise up in conspicuous points and ridges. These features are well exhibited in the southern parts of Perth and Forfar, where the natural weathering of these rocks has resulted in the development of a land-surface more diversified and picturesque than that of any of the remaining unaltered sedimentary systems. In Hereford and South Wales, where the Old Red Sandstone strata are of the Scottish type, but are destitute of associated igneous rocks, the scenery is much less diversified; but to the south of the Bristol Channel, where the beds are harder and slatier, their erosion has given origin to the beautiful scenery of North and South Devon. The *Silurian and Cambrian Systems* consist of hard flaggy gritstones and shales, but little varied in composition and texture, and are much less easily worn down by aqueous agencies than the strata of the more recent formations. Where they are not interfered with by igneous intrusions—as in the uplands of South Scotland and Central Wales—they form broad swelling plateaux, with a soft undulating surface, usually grass-clad and pastoral, but occasionally obscured by gloomy stretches of heath and moorland. Where they contain much igneous rock, they rise up grandly in majestic peaks and summits, as in the beautiful Lake District of the north of England, and in the mountain-masses of Arenig, Cader Idris, and Snowdon. Finally, the more or less crystalline strata of the *Metamorphic Systems* excel all others in the grandeur of the scenery to which they give origin—here sweeping up in ridges of vast extent, there weathering down into splintery peaks and crags, as in the mountain-regions of Scandinavia and the Northern Highlands, and in the summits of Ben Lawers, Schiehallion, and Ben More.

40. Such are the leading features of the stratified systems, and by such, with a little practice, they may be readily detected in the various areas they occupy. As with the stratified so with the unstratified; each great group — Volcanic, Trappean, and Granitic — has its own

peculiar and distinctive features. The *Volcanic*, as already stated, are generally associated with the more recent formations, and consist of trachytes or greystones, various lavas, scoriæ, and similar products. They rise up in dry rocky hills, more or less conical and crateriform (having bowl-shaped cavities at top, from Gr. *krater*, a bowl); and these are perhaps less frequently grouped round some common centre than arranged in linear directions. The *Trappean* (Swedish *trappa*, a flight of steps), from the step-like or terraced aspect of many of the hills they compose, consist of greenstones, basalts, felstones, porphyries, trap-tuffs, and other kindred rocks, and are generally associated with the secondary and upper primary strata. They are usually arranged in hill-ranges more or less persistent, and, from their higher antiquity and longer subjection to wasting influences, are more worn into rounded heights, exposed crags, slopes, and terraces, which confer on the landscape a beauty and diversity peculiarly their own. The *Granitic*, or oldest series of igneous rocks, consists of granites, syenites, elvanites, and the like, which, from their more ancient and deep-seated relations, are generally hard and crystalline in texture and massive in structure. They are of frequent occurrence in the central parts of the higher and older mountain-chains, being often surrounded by the splintery peaks and abrupt ridges of the metamorphic schists, but presenting of themselves broad massive shoulders of cold, sterile moorland and unprofitable heath. Vesuvius, Etna, and the hills of Auvergne, may be taken as typical examples of the Volcanic group of igneous rocks; the Ochils and Sidlaws, of the Trappean; and the Grampians, the Wicklow and Cornish mountains, of the Granitic.

Connection between Geology and Physical Geography.

41. Understanding the nature of the preceding subdivisions, the student will be able to attach some intelligible idea to such phrases as "the river cutting its way through secondary strata;" "lying in an irregular tertiary basin;" "crossing a plateau of triassic sandstones;" "a cold, retentive soil, derived from the subjacent carboniferous rocks;" "intersected by a low range of trap-hills, whose grassy

slopes and terraces;" "bounded by sterile granitic ridges, whose snow-clad summits;" and hundreds of others that are of continual occurrence in geographical descriptions. He will still more fully perceive the intimate connection of Geology with his own immediate science, when he reflects that many of the soils which give character and colouring to vegetable growth are derived directly from the disintegration of the subjacent rocks, and are further affected in their fertility by the porous or retentive nature of the beds on which they rest. The soil derived from the Chalk, for instance, is light and absorbent; hence the short sweet herbage of the "downs" of the south of England; that derived from the marls of the New Red Sandstone is stiff, retentive, and less fitted for tillage than for pasture; the disintegration of trap-rocks, rich in soda, potash, and lime, yields a fertile, genial soil, which their structural fissures ever keep dry and pulverulent; while the scanty soil afforded by an impervious granite is poor, cold, and barren. We have seen, moreover, that every geological formation is more or less characterised by its own special features. The soft rounded outline of a chalk range is altogether distinct from the slopes, terraces, and conical heights of secondary trap-hills; while these, on the other hand, are widely different, both in outline and in vegetable covering, from broad-shouldered mountains of granite, or the splintery peaks of slaty, metamorphic strata. In fine, these formations and rock-groups constitute the framework on which the geographical features are moulded; and their inherent characters, as subject to external and internal change, have produced, and are ever producing, new variety of superficial aspect or scenery. Geology and Geography are inseparably connected; and thus it is that some acquaintance with the nature and sequence of the rock-formations that constitute the solid crust, and with the causes that produce them, becomes so indispensable to the student of Physical Geography.

RECAPITULATION.

42. In the preceding chapter we have directed attention to the rocky structure of the globe as that which gives colour and character to all external phenomena, and is

therefore of paramount importance to the student of Physical Geography. We have spoken of the "crust," composed of materials that can be seen and investigated, as distinct from the "interior," of which nothing can be known by direct observation. This crust, composed of stratified and unstratified, or of water-formed and fire-formed rocks, is held in habitable equilibrium between the disintegrating forces of air and water from without, and the reconstructing forces of fire from within. To these two opposing powers are chiefly owing the continuous geological modifications of the earth's crust—each modification characterising a period during which certain rocks were formed, and the remains of plants and animals that then lived entombed in them in greater or less perfection. These formations being arranged by the geologist in chronological sequence, and each varying in mineral character, and consequently conferring on the landscape different aspects, it is of importance in Physical Geography to know the order of this arrangement, and the nature of these distinctions. These *formations*, we stated, have been arranged into certain *systems*, and these systems again grouped into certain *periods*, according to the leading features of their fossils, thus:—

1. Post-Tertiary, 2. Tertiary,	CAINOZOIC.
3. Cretaceous, 4. Jurassic, 5. Triassic,	MESOZOIC.
6. Permian, 7. Carboniferous, 8. Devonian, 9. Silurian, 10. Ordovian, 11. Cambrian,	PALÆOZOIC.
Metamorphic,	EOZOIC.

43. As with the stratified systems, so with the unstratified — their arrangement into VOLCANIC, TRAPPEAN, and GRANITIC, expressing the relative position and nature of the great igneous groups that give character and indi-

viduality to the hills and mountain-ranges of the globe. So far, then, as diversity of surface, fertility of soil, character of landscape, and similar peculiarities, are concerned, the connection between Physical Geography and Geology is intimate and inseparable; hence the necessity that the student of the one should be less or more acquainted with the leading facts of the other. It by no means follows, however, that the student of Geography should be deeply read in the theoretical problems of Geology. An acquaintance with its general principles, and the causes that are incessantly productive of new modifications of the earth's crust, the leading formations that compose that crust, the nature of their rocks, and the character which these rocks impart to the soil and landscape, is all, or nearly all, that he requires.

IV.

DISTRIBUTION OF LAND AND WATER.

Their Relative Positions and Areas.

44. HAVING noticed the general conditions of the earth as a member of the solar system, and having also adverted to the structure of its own rocky crust as the groundwork of all geographical diversity, we now proceed to consider the more intimate relations of its surface as composed of Land and Water. When we speak of the earth's surface as composed of land and water, we mean that all the more elevated portions of the crust stand out as dry land, while the lower and more depressed are covered by the waters of the ocean. Geologically speaking, the relations of land and water are continually, though slowly, undergoing change and modifications; geographically speaking, and within the limits of such mutation, what are the respective areas of land and water, their positions on the earth's surface, their actions and reactions on each other in consequence of their different extents, positions, radiation of heat, &c.? and what the influence of these reactions on currents, winds, rains, and all those kindred phenomena that constitute climatic diversity? The present distribution of land and water tends to the production of certain physical and vital results, and the explication of these results forms the sum and substance of our science; but no portion of the present distribution could be altered, either in its position, extent, or configuration, without being accompanied by a modification of these results, so intimately is the one element bound up with the other in the production of a definite and harmonious whole.

45. As formerly stated, the superficial area of the globe

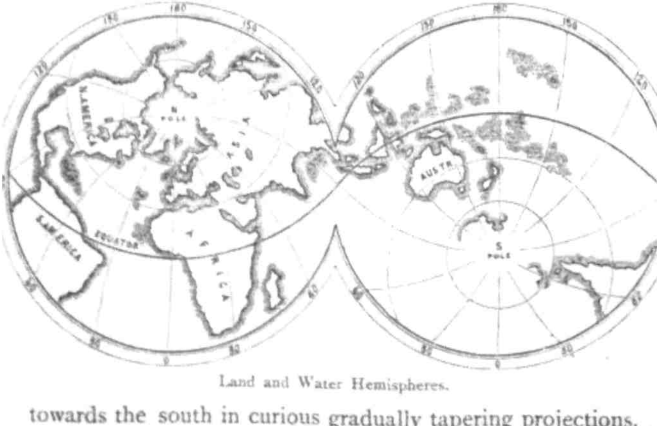
has been computed at 197,000,000 square miles. Of this amount about 51,500,000 consists of dry land, and about 145.500,000 of water. The proportion of land to that of water is therefore nearly as *one* to *three*; or, expressing it fractionally, while *one-fourth* of the earth's surface is composed of dry land, the other *three-fourths* are covered by the waters of the ocean. Considered in hemispheres, northern and southern, the proportions of land and water are nearly as follows:—

Northern Hemisphere,	Land,	38,000,000 square miles.	
Do.	do.	Water, 60,500,000	„
Southern Hemisphere,	Land,	13,500,000	„
Do.	do.	Water, 85,000,000	„

The boundaries of this terraqueous arrangement (Lat. *terra*, land; *aqua*, water) are extremely irregular. Here the land spreads out in broad unbroken masses, there the waters stretch away in vast continuous expanses; here the land rises up in mere specks and fragments, there the water inserts itself among them in areas equally limited and irregular. Here the land juts out boldly into the ocean, there the ocean runs sharply into the land; here the land trends with a uniform shore-line for leagues, there the ocean embays itself with gentle curves into the bosom of the land. Although this distribution seems to obey no regular order, and has been continually changing throughout all geological time, yet we may rest assured—and not the less sure because we are unable to discover it—that there is a law governing the insensibly varying relations of sea and land, and defining their respective amounts. The boundary between the land and water is known as the *shore-line* or *coast-line*—the former having more especial reference to the margin washed by the waves, the latter to the terrestrial verge that opposes the ocean. The space alternately covered and laid bare by the tides is termed the *beach* or *strand;* and the fringe of land bordering on, and more or less influenced by its proximity to, the sea, is spoken of as the *seaboard* of a country or continent. This sea-belt is generally marked by the peculiarity of its plants and animals, as well as by the character of its inhabitants—these differing in many points from those of the interior or inland districts. Thus the plants and animals are affected by the sea-breezes and other oceanic influences, while the inhabitants are more

maritime than agricultural in their pursuits, besides presenting greater admixture of race from invasion and settlement among them of adventurers from other countries. In like manner, on the configuration of the shore-line depends much that relates to the climate as well as to the industry and commerce of a country. A regular and unbroken coast is generally an exposed and ungenial one, and one unfavourable to maritime enterprise; while one indented with gulfs and creeks and bays has more of genial diversity, and is better fitted for the purposes of navigation and commerce.

46. *A glance at the Map of the World will show that the* land-masses are situated chiefly in the northern hemisphere —there being about three times as much land in the northern as there is in the southern hemisphere. And if we look at the distribution of this land as regards the zones of temperature, we will find that the greatest proportion is situated in the north temperate zone, or in that which contains all the better portions of Europe, Asia, and North America; while only comparatively narrow or isolated tracts are cut directly by the equator or central torrid line. Another glance at the map will show that, while the land lies in broad and unbroken masses towards the north, it stretches

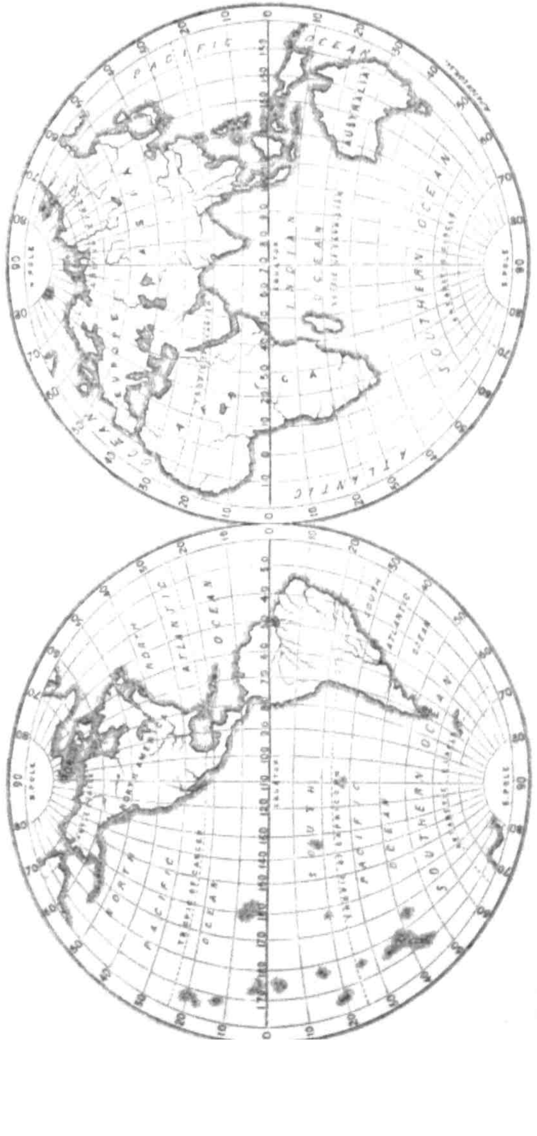


Land and Water Hemispheres.

towards the south in curious gradually tapering projections. Again, if the globe be divided into two hemispheres, as shown in the accompanying illustration—the one having

THE WORLD.

Western Hemisphere. Eastern Hemisphere.



London for its pole, and the other having that of Antipodes Island, near New Zealand—the former will be found to contain nearly all the land-masses, and may therefore be called the *Continental* or *Land Hemisphere*, while the other contains the greater proportion of the water expanses, and may for that reason be termed the *Oceanic* or *Water Hemisphere*. These and other noticeable facts connected with the arrangement of sea and land have been adverted to by geographers; and though it must be confessed that many of their comparisons are more curious than suggestive, there can be no doubt that the present distribution is the result of some great cosmical law—a law concerning the nature of which neither Geology nor Geography can as yet give any certain indication. This much, however, Geology has shown, that the present arrangement is not the arrangement that obtained in former ages, and that lands existed where the waters now roll, and seas extended where continents are now established. We can readily account for the minor modifications of coast-lines—why some portions, composed of hard enduring rocks, should stand out in bold projections, while others, consisting of soft and wasting material, should be worn into bays and irregular recesses; but of the greater forces that slowly upheave some regions, and as gradually submerge others, we are altogether ignorant. But while we fail to account for the present distribution of sea and land, and while we find that it is continually undergoing modifications under the operation of geological forces, we know that these changes are so silent and gradual as scarcely for ages to interfere with our ideas of geographical permanence and stability.

The Land—Its Subdivisions, Extent, and Nomenclature.

47. Admitting this condition of the terraqueous surface, it will be seen, on further reference to the map, that the Land is broken up into two main masses—that of the Eastern Hemisphere, embracing Europe, Asia, and Africa, and described, from its being the only portion known to the ancients, as the *Old World*,—and that of the Western Hemisphere, including North and South America, and known (from its comparatively recent discovery by Co-

lumbus in 1492) as the *New World*. Properly speaking, there are only two great continuous land-masses or *continents* (Lat. *con* and *tenens*, holding together)—that of the Old World and that of the New; but geographers usually speak of six continents or principal sections—viz., those of *Europe*, *Asia*, *Africa*, *North America*, *South America*, and *Australia*. Australia and its contiguous islands, together with those of the Southern Ocean, are frequently grouped as the sixth great division, under the title of *Oceania;* but this and other minor distinctions will be noticed more fully when we come to treat of the continents in detail. The areas of these respective continents, or *quarters*, as they are sometimes termed (though the "four quarters" of our forefathers embraced only Europe, Asia, Africa, and America), have been computed, with their respective islands, as follows :—

Old World, or Eastern Continent,		31,250,000	square miles.
Europe,	3,725,000		,,
Asia,	16,165,000		,,
Africa,	11,360,000		,,
New World, or Western Continent,		14,900,000	,,
North America,	8,080,000		,,
South America,	6,820,000		,,
Oceania, or Maritime World		4,200,000	,,

The islands included in the above estimate are sometimes solitary and independent, as Iceland, Spitzbergen, Novaia Zemlia, Madagascar, New Zealand, &c.; are occasionally curiously connected with the extremity of some peninsula or continent, as Tierra del Fuego, Sicily, Ceylon, Tasmania, &c.; but, on the whole, are most frequently found in clusters or *archipelagos* (a term originally applied to the Isles of Greece), as the West India Islands, the Isles of Greece, the India Islands, the Japan Isles, and many others that must at once present themselves on the most cursory inspection of the Map of the World.

48. In describing the features and peculiarities of the land, geographers make use of the following designations, which, though familiar in everyday language, may here, for the sake of method, be briefly summarised. Thus, a *continent*, as already indicated, is any extensive region uninterrupted by seas; an *island*, any smaller portion surrounded by water; a *peninsula* (Lat., almost an island), a portion nearly surrounded by water; an *isthmus*, the narrow neck

that connects two adjacent masses of land, or a peninsula with the mainland; and a *cape*, *promontory*, *headland*, or *ness*, a point of land jutting out into the water. Besides these terms, which refer to the contour or disposition of the land, as surrounded by water, there are others which relate to surface configuration or vertical relief. Thus, extensive flats are known as *plains*, *steppes*, *prairies*, *savannahs*, *pampas*, and the like; smaller flats, as *valleys*, *dales*, *levels*, *straths*, *carses*, &c.; lands elevated more or less abruptly above the general surface are spoken of as rising into *hills*, or, still higher, into *mountains*; hills and mountains may stand less or more apart from each other and be *isolated*—may occur in *groups*, as if connected with a common centre—or they may stretch away in determinate courses known as *chains* and *ranges*; while flattish elevated tracts are spoken of as *table-lands* and *plateaux*.

The Water—Its Subdivisions, Extent, and Nomenclature.

49. Though encircling the globe on every side, and in all its parts most intimately connected with one great ocean, the Water is still divisible into certain areas that are more or less defined by the intervention of the land. Thus, on the west of the Old World, and between it and the New World, extends one main division known as the *Atlantic* (so called by the ancients from its washing the western base of Mount Atlas in Africa); on the west of the New World, and between it and the Old, expands another natural division, termed the *Pacific* (from its comparative freedom from storms); while between Australia and its contiguous islands on the east and Africa on the west lies the *Indian Ocean*. It is usual, however, to speak of *five* great oceans—viz., the *Atlantic*, *Pacific*, *Indian*, *Arctic*, *Antarctic*—the last two lying respectively within the arctic and antarctic circles. In geographical descriptions it is also useful to employ the terms "North and South Atlantic" and "North and South Pacific," and to speak of the expanse that stretches away in unbroken vastness between the Indian Ocean and the South Pole as the "Great Southern Ocean." The areas of the three chief expanses are usually stated as follows:—

Pacific Ocean,	50,000,000	square miles.
Atlantic Ocean,	25,000,000	,,
Indian Ocean,	17,000,000	,,

Being ignorant of the amount of land that lies within the arctic and antarctic circles, and also of the exact extent of many islands both in the northern and southern oceans, the above must be held as approximations merely; and further, as amounts that do not embrace the areas of minor and *inland seas*—such as the North, Baltic, Mediterranean, Red, Black, Caspian, &c.—which occupy, as will hereafter be seen, considerable and important spaces on the surface of the globe.

50. In treating of the waters of the globe, though there is, strictly speaking, only one great ocean, the term *ocean* is applied to the large uninterrupted expanses above defined; smaller areas are known as *seas;* gradual bendings of the water into the land as *bays;* deeper indentations as *gulfs;* minor and sudden indentations as *creeks, inlets, arms,* &c.; the narrow belts or openings connecting two adjacent seas as *straits* or *channels;* and where the sea stretches inland to receive the waters of a river, such an expanse is known as a *firth* or *estuary*. Besides these, there are other local and restricted terms—as the *fiords* or rocky inlets of Norway—the *lochs* or lake-like sea-arms of Scotland—the *lagoons* or shallow intercepted sheets that occur along the shores of the Adriatic and other seas; but these will be best described under the respective areas to which they belong. Again, referring to the depth of the ocean, whose bed seems to be almost as varied as the surface of the dry land, voyagers speak of *deeps* and *pits;* of *shoals* and *banks;* of *rocks* and *reefs;* of *sounds* that may be readily reached by the sounding-line; of *roads* and *roadsteads* for anchorage; of *harbours* or land-locked inlets for shelter; of *offings* or *fairways*. The meanings of these and similar terms are so obvious as to require no special definition.

51. Besides the great oceans and inland seas above alluded to, and which all consist of salt water, there are other considerable volumes that belong more especially to the land, and which consist mainly of fresh water—comparatively few being brackish or saline. These are the *springs* issuing from the earth's crust, and more or less impregnated with the mineral substances derived from the strata through which they have percolated; the *streams* or runnels of water formed by the union of several springs; the *rivers* formed by the union of streams, and often traversing whole

continents with gradually increasing volumes; and the *lakes*, which occupy depressions in the land, and most frequently lie along the courses of rivers, though occasionally occurring isolated, and apparently fed by springs; or, if receiving the waters of a river, have no river of discharge, but give off their surplus water by evaporation. The amount of surface occupied by these inland waters it is impossible to estimate with anything like accuracy; but the main volumes, as will be seen when we come to treat of the "River-Systems," are the North American lakes, the lakes of Northern Europe and Central Asia. The greater rivers are the St Lawrence, Mackenzie, and Mississippi in North America—the Amazon, Orinoco, and La Plata in South America—the Nile and Niger in Africa—the Ganges, Indus, Yang-tse-kiang, Lena, Yenisei, and Obi in Asia—and the Volga and Danube in Europe.

Action and Reaction of Land and Water.

52. Such is the relative distribution and such the general features, of the land and water that form the surface of the terraqueous globe. Whatever may have been their distribution in former ages as revealed by geology, one thing is obvious, that in the present era they are, within certain limits of change, mutually adapted and harmoniously adjusted. The land is more rapidly heated and cooled than the water, and thus, while parched and thirsty in summer, it is refreshed and vivified by the moisture evaporated from the more extensive ocean; while in winter the effects of its tendency to grow colder are modified by the heat given off by the ocean, whose slower radiation renders it, as it were, a great storehouse of heat for the exigencies of the land. Besides this interchange of heat and moisture, there is also the interchange of aerial currents and winds caused by the unequal effects wrought upon the two great surfaces by the heat of the sun; and thus, as will be more fully explained hereafter, the whole machinery of climate—hot winds, cold winds, vapours, rains, and the like—is set agoing by the primary differences existing between land and water.

53. As the terraqueous surface is at present arranged, a certain amount of moisture is evaporated from the ocean and carried to the land, a certain amount of heat is inter-

changed, certain winds blow at certain seasons, certain tides rise and fall, and certain currents flow in performance of certain functions; but all this would be changed by the slightest alteration either in the relative areas, in the relative configurations, or in the relative positions, of land and water. In their present areas, configurations, and dispositions, the two elements are harmoniously co-adapted for the production of certain results, geological, climatological, and vital; and the student must readily perceive how the force of tides and waves and currents would be altered, the climate of regions changed, and their plants and animals affected, by the slightest disturbance in the existing terraqueous arrangements. Let the land, instead of being distributed chiefly in the northern hemisphere, lie mainly under the equator; let the continents, instead of stretching north and south under different latitudes, trend in an easterly and westerly direction under the same latitudes; or let North America be severed from South America, and Africa from Asia,—and then see how the winds, the tides, the ocean-currents, and all the great influences that affect climate, and consequently the distribution of plant-life and animal life, would be altogether and essentially altered. The terraqueous arrangements of time past, with all their accompanying phenomena, belong to Geology; the arrangements of the present constitute the sum and substance of Physical Geography.

RECAPITULATION.

54. The facts detailed in the preceding chapter are so simple and obvious, that they require little recapitulation. The surface of the globe, or that which comes in contact with the atmosphere, is partly occupied by land and partly by water—the former forming more than a fourth, and the latter about three-fourths, of the entire area. On a cursory inspection of the Map of the World, the land will be seen to resolve itself into two main masses—the Eastern Hemisphere, or Old World, and the Western Hemisphere, or New World; and these by geographers are usually further

subdivided into the so-called quarters or continents of Europe, Asia, and Africa in the former, North and South America in the latter, together with a south or insular division, embracing Australia, &c., under the name of Oceania. Of these continents the greater portion lie in the northern hemisphere. The broader masses of land spread out towards the north, and gradually narrow towards the south in the cape-like projections of South America, Africa, Hindostan, and the Malayan peninsula. The ocean, though encircling the globe on every side, and stretching from pole to pole, is also arranged in areas more or less defined by the intervention of the land-masses. The main divisions are, the Atlantic, the Pacific, Indian, Arctic, and Antarctic Oceans, which for convenience of description are frequently subdivided into North and South Atlantic, North and South Pacific, Northern, Southern, and Polar Seas.

55. The technicalities employed in treating of the relations of land and water—shore-line, coast-line, island, peninsula, isthmus, cape, bay, gulf, strait, channel, and the like—are so obvious, and of such frequent use in everyday language, as scarcely to require any special explanation. The physical results arising from the present distribution of sea and land are manifested chiefly in tides, ocean-currents, unequal rate of heating and cooling of surface, and as a consequence winds, vapours, rains, and all the other phenomena that give rise to climatic diversity. What may be the cause of the present arrangement of sea and land—why the land should lie chiefly in the northern hemisphere, and largely within the temperate zone, while it disappears in a succession of narrow cape-like lobes towards the south—neither Geology nor Geography can determine. One thing, however, is certain, that it is part of a great geological sequence of continuous oscillations between sea and land, each change being attended by its own physical and vital phenomena; and that, as in the past history of the globe so in the present, no alteration in this terraqueous arrange-

ment can take place without a corresponding alteration in all the essentials of Physical Geography. We could not, for example, alter the disposition of either of the great continents, nor upraise it, nor depress it, without interfering to that extent with all the oceanic and climatic phenomena of the earth, and, as a consequence, with the nature and distribution of its Flora and Fauna; and not only with the Flora and Fauna, but with its human occupants also, in all that relates to their physical and mental peculiarities—their avocations and industries.

V.

THE LAND—ITS SUPERFICIAL CONFIGURATION.

56. HAVING glanced at the distribution of land and water, and their general relations to each other as composing the terraqueous surface, we may now proceed to consider their special features,—the mountains, table-lands, plains, and valleys of the one—the composition, depth, bottom, temperature, tides, and currents of the other. And first, in the present chapter, of the Land, whose features are more within our reach, and have been longer and more minutely the subjects of geographical investigation. Where, for instance, is the place of any portion of land on the surface of the globe? This, in geographical language, is its *relative position*. What is the outline of its form as surrounded by the ocean? This is its *contour*. How, again, does it rise above the water; and what are the surface inequalities presented to the atmosphere by which it is enveloped? This is its *vertical relief*. Position is the place it occupies on the surface of the globe; contour the outline bathed by the waters of the ocean; vertical relief the surface-line that rises into the atmosphere: and the student will readily perceive that upon these three elements of position, contour, and relief, depend the climate, physical aspects, and vital diversity of any portion of the dry land.

Relative Position.

57. Latitude and longitude, we have said, determine the position of any spot on the earth's surface, be it islet, island,

or continent; and just as these limits bring it within tropical, temperate, or arctic zones, so will its climate and products assume aspects of a corresponding character. No doubt climatic conditions are greatly modified by contour and altitude, but position is the main determinator of a country's character, and must ever continue to be so under the existing relations of the earth in the solar system. How different, for instance, the physical and vital characteristics of Europe and Asia had they lain mainly within tropical, instead of stretching, as they now do, mainly along temperate latitudes! How different also the condition of North and South America, if, instead of stretching from north to south, through all the different zones of temperature, they had lain, like the Old World, from east to west, along the same parallels of latitude! Or, how different the climate of Great Britain, if, instead of trending away into the Northern Sea it had stretched westward into the milder waters of the Atlantic! Position, in fact, is an all-important element in geography; hence the value of accurate mapping, and a knowledge of this mapping to every one, whether engaged in commercial pursuits or in the study of natural phenomena.

Contour or Horizontal Disposition.

58. Though Geology and Geography are alike unable to account for the present disposition of sea and land, there are still some features in the contours of the respective continents that demand a passing notice. Not that we can account for these features, nor that they are deserving the attention some geographers have bestowed upon them, but simply because they are arrangements productive of obvious results, and as such cannot be overlooked in our review of physical causation. Thus—

1st, Though the greater bulk of the land lies in the northern hemisphere, the greatest extension of the Old World continent is from east to west, while that of the New World is from north to south. In this way the Old World, lying largely along the same zones, presents a greater uniformity of external conditions; while the New World, crossing the zones—frigid, temperate, and torrid—is subject to a greater diversity of temperature, and, as a

consequence, to all the conditions that arise from this diversity.

2d, Both continents attain their greatest dimensions from east to west along the same parallel of latitude—namely, that of 50° north—a disposition that places much of North America, Europe, and Asia within the temperate zone; while only the narrower portions of South America, Africa, and the East India Islands lie directly under the burning heat of the equator.

3d, Both continents, as formerly noticed, spread widely towards the north, where they nearly approach each other, and terminate broadly along the same parallel (72° N.), or nearly so; while towards the south they gradually grow narrower, and terminate in far-separated promontories.

4th, In like manner, the direction of all the principal spurs and peninsulas in both continents (California, Florida, Greenland, Scandinavia, Spain, Greece, Hindostan, Malaya, &c.) is towards the south—a feature by far too general not to suggest to the inquiring mind a sameness in the producing cause.

5th, These southward-trending spurs, moreover, are in most instances curiously accompanied by an outlying island or islands—as South America by Tierra del Fuego and the Falkland Islands, Africa by Madagascar, Hindostan by Ceylon, and Australia by Tasmania.

6th, The general dispositions of the continents and larger islands is in the direction of their principal mountain-axes: so that, given the direction of the mountain-chains, we know the longitudinal disposition of a continent; or, given the direction of a continent, we can determine the strike of its mountains.

7th, The almost complete separation of South America from North America, of Africa from the Old World, and the complete severance of Australia from Asia, as well as the curious resemblance that obtains between North America with the West India Islands on its south-east, Europe with the Grecian Islands on the south-east, and Asia with the Indian Archipelago on the same quarter, are curious coincidences that have long been noticed by geographers.

8th, The general tendency of islands to arrange themselves in clusters or archipelagos is a fact also suggestive of a common geological cause and origin.

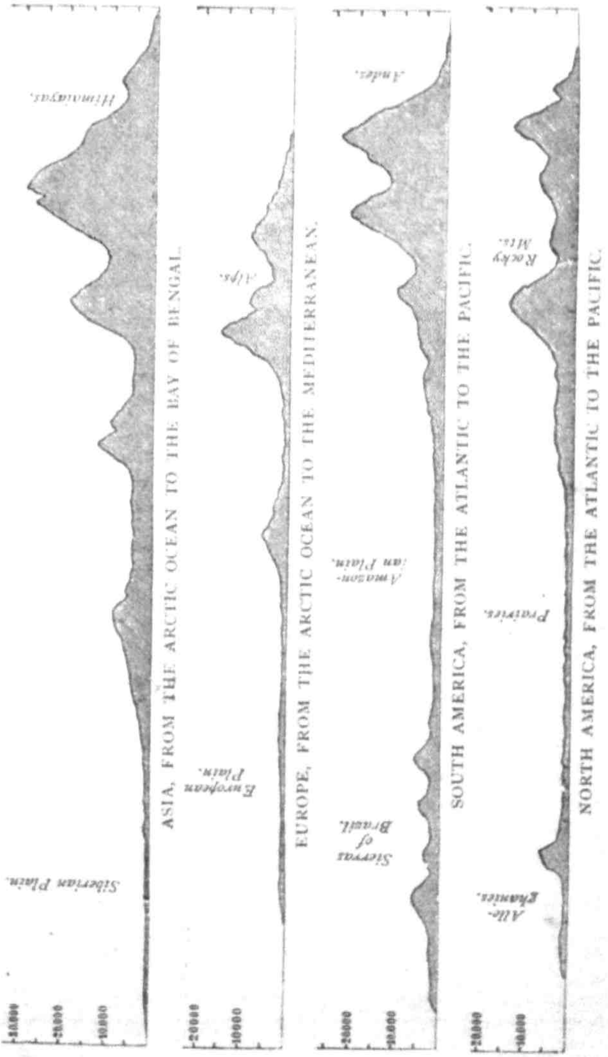
And, lastly, the numerous indentations of the sea that confer irregularity and extent of coast-line on the land in the northern hemisphere form a feature that strongly contrasts with the uniform and unbroken coasts of South America, Africa, and Australia in the southern hemisphere. Indeed, this last relation—viz., that of a broken and deeply indented coast-line, furnished with peninsulas, gulfs, inland seas, and harbours—is one of the most important in Physical Geography, as on it depend greater diversity of climate and productions, and all those facilities for navigation and commerce which confer on nations their wealth, power, and independence. Europe and North America stand pre-eminent for their extent of coast-line, the former having one mile of coast for every 170 square miles of surface, and the latter one mile of coast for every 260 square miles—a proportion more than double, and in some instances even four times, that of the other continents; hence one great physical reason for the maritime enterprise, commerce, industry, and civilisation of their inhabitants.

59. Besides the preceding analogies, there are several others that have been noticed by geographers; and though such comparisons are often more fanciful than real, they are all less or more suggestive. But whatever may have been the causes that produced the present arrangement of the land-masses, no change could take place in their relative situations without being attended by corresponding changes in the nature of their climate and in the character of their vegetable and animal inhabitants. Had they lain chiefly within the tropics, been situated partly in the northern and partly in the southern hemisphere, with a broad belt of tropical ocean between, been arranged either longitudinally or latitudinally in parallel zones, or been broken up into smaller masses by the more frequent intervention of the ocean, a totally different set of climatic agents would have prevailed, and would have been attended by a totally different distribution of plants and animals. As it is, and in the words of an eloquent authority (M. Guyot), "each of these terrestrial masses, considered as a whole, as an individual, has a particular disposition of its parts, and the forms which belong to it—a situation relatively to the rays of the sun, and with respect to the seas or the neighbouring masses — which is not found identically repeated in any

other. All these various causes excite and combine, in a manner infinitely varied, the play of the forces inherent in the matter which composes them, and secure to each of them a climate, a vegetation, and animal life—in a word, an assemblage of physical characters and functions—which are peculiar to it, and which really give it something of individuality." It is this *individuality* of the land-masses, and the study of its character, which constitutes, in fact, the very purport and essence of Physical Geography.

Vertical Relief or Elevation.

60. Next to the *contour* or horizontal configuration of the land, the most important feature is its *vertical relief*, or elevation above the level of the ocean. As the position of an island a few degrees north or south, its disposition along the parallels of latitude or along the meridians, or its configuration as broken up by seas or lying in one unbroken mass, must each affect the nature of its climate, so its vertical relief is productive of similar results—every rise of 300 feet or thereby being sufficient to diminish the temperature by one degree of Fahrenheit's thermometer. If we cannot determine with satisfaction the causes that have produced the existing position and contour of the continents, we know, at least, that the main instruments of their surface diversity into mountain and valley, table-land and plain, are the volcanic forces acting from within. These, in obedience to some great law, have been continuously and gradually shifting place from the earliest times of geologic history; prevailing at one time, and extensively, along the old granitic ranges of Europe, Asia, and Africa—at another, and with equal intensity, along the secondary hills of the same continents—and now, at the present day, with apparently unabated vigour, along the main ridges of America, the islands that skirt the eastern shores of Asia, and the groups that stud the bosom of the Pacific (see Map of Volcanoes, p. 85). These successive shiftings and upheavals form, in fact, part and parcel of the great machinery of the globe—a machinery by which the sea-bed is upheaved into new land, and old surfaces submerged beneath the ocean—and this continuously, successively, and, in all likelihood,


ASIA, FROM THE ARCTIC OCEAN TO THE BAY OF BENGAL.
Himalayas.
Siberian Plain.
30000
20000
10000
EUROPE, FROM THE ARCTIC OCEAN TO THE MEDITERRANEAN.
Alps.
European Plain.
20000
10000
SOUTH AMERICA, FROM THE ATLANTIC TO THE PACIFIC.
Andes.
Amazonian Plain.
Sierras of Brazil.
20000
10000
NORTH AMERICA, FROM THE ATLANTIC TO THE PACIFIC.
Rocky Mts.
Prairies.
Alleghanies.
20000
10000

in an order which geology shall one day or other be enabled to determine. Besides the more obvious operations of the earthquake and volcano, there is also that slow but gradual elevation and depression of vast regions (*e.g.*, the uprise of northern Scandinavia, the depression of South Greenland, the uprise of the Arctic Islands, &c.), which, in course of time, must effect most important changes both on the distribution and altitude of the land; and to these combined forces, assisted by the wasting and wearing of air and water, are to be mainly ascribed the principal features in the vertical relief or superficial diversity of the land.

61. Among these features of vertical relief may be noticed—

1st, That in all the continents there is a gradual rise from the sea-shore towards certain points or ridges in the interior —the spaces occupied by a few depressed areas, as the Caspian, Dead Sea, &c., being too limited to affect the results of the general configuration. These ridges or points of maximum swell form the grand *watersheds* of their respective continents, and a glance at the courses of the principal rivers will at once direct the eye to the line of these mountainous elevations.

2d, In all the continents this line of greatest elevation does not occupy the centre, but is placed more towards one side than another; hence arise two slopes of unequal length —the long side forming the *slope*, and the shorter the *counter-slope*, of the continent. In the Old World (as may be seen by referring to the sections on p. 63) the long slopes are turned towards the north, and the short towards the south; while in the New World the gentle slope is towards the east, and the short and rapid one towards the west.

3d, Though this difference of arrangement in the slope and counter-slope takes place in the two worlds, there is still in both a general flattening of the land towards the north, and a general rise and irregularity of its surface towards the south—a disposition that tends to counteract the effects of the northern cold, and to temper the burning heats of the tropical regions. "If this order were reversed," says M. Guyot, "and the elevations of the land went on increasing towards the north, the most civilised half of the globe, at the present day, would be a frozen and uninhabitable desert."

4th, That the grand elevations or mountain-ranges lie in

the direction of the greatest length of a continent; in fact, it is the great lines or *axes* of upheaval that confer on the continents their main relief or configuration. Thus, in the New World, whose greatest length is from north to south, the ranges of the Andes and Rocky Mountains, the Cordilleras of Brazil, and the Alleghanies of the United States, stretch all more or less regularly in the same direction. In the Old World, on the other hand, whose greatest length is from east to west, the ranges of the Pyrenees, Alps, Carpathians, Caucasus, Himalayas, and Altai, lie chiefly in the same direction, throwing the great rivers to the north and south of these watersheds. The backbone, if we may so speak, of the New World, is the great mountain-chain, or rather chains, that extend in the same linear direction from Patagonia on the south to Alaska on the north; while the backbone or framework of the Old World is similarly composed of a series of ranges that extend with but little interruption from the Pyrenees on the west to Kamtchatka on the east.

5th, As with the continents, so with the principal islands and peninsulas, they are all less or more continuously traversed by mountain or hill ranges in the direction of their greatest length—as witness Scandinavia, Italy, Kamtchatka, Malaya, the islands of the Indian Archipelago, Madagascar, California, and Greenland.

62. Reserving the arrangement of the world's highlands into mountain chains and systems for subsequent consideration, it may be noticed, in the meantime, that the loftiest ridges in the vertical relief of the land are those of the Himalaya, in Central Asia, whose highest peak is, in round numbers, 29,000 feet; next those of the Andes, in South America, 24,000 feet; the Equatorial Ranges of Africa, 20,000 feet; the Cordilleras of Mexico, in North America, 17,740 feet; the Alps, in Europe, 15,740 feet; and the highest ascertained points in Malaya, Australia, and Polynesia respectively, 15,000 feet, 7000 feet, and 16,000 feet. These altitudes, however, convey no idea of the general relief of the several continents, whose superficial aspects depend more on the table-lands and plains, the hill-ranges and valleys, than on the extreme heights of their principal mountains. Indeed, so small a proportion do these extreme ridges bear to the great mass of the continents, that it has

been calculated by Humboldt that the Alps, spread equally over the surface of Europe, would raise the general level not more than 21 feet; while the vast mountain-chains of Asia, treated in a similar manner, would not add more than 150 feet to the general elevation of that continent. Blending all their heights and hollows into a general average, the *mean elevations* of the respective continents above the sea-level have been calculated as follows: Europe, 1342 feet; Asia, 2264 feet; Africa, 1800 feet; North America, 1496 feet; and South America, 2302 feet; or, taking the whole —continents and islands, mountains and plains—the mean elevation of all the land has been estimated at somewhat less than 1000 feet.

63. As a feature of the land, its vertical relief is of infinite importance—physically and vitally. On it depend in a great measure not only the temperature and climate, but, as a consequence, the intensity of geological action, and the nature and luxuriance of vegetable and animal life. The greater the altitude the scantier the flora and fauna; the more diversified the surface, the more abundant the species, and more numerous the individuals. A tame and uniform surface is tantamount to sameness and paucity of life; an irregular and varied one is marked by a corresponding diversity and exuberance of living forms.

RECAPITULATION.

64. It will be seen, from the facts stated in the preceding chapter, that the three great elements in the configuration of the land are, relative position, contour, and vertical relief. By *relative position* is meant the place an island or continent occupies on the surface of the globe; and just as this position is frigid, temperate, or tropical—as it lies in broad parallelisms along the same zone, or crosses meridionally two or more zones—so will its climate be genial or ungenial, uniform or diversified. The causes that have determined the position of the existing continents lie far as yet beyond the indications of science, though we may rest assured that in the gradual shiftings of volcanic energy from

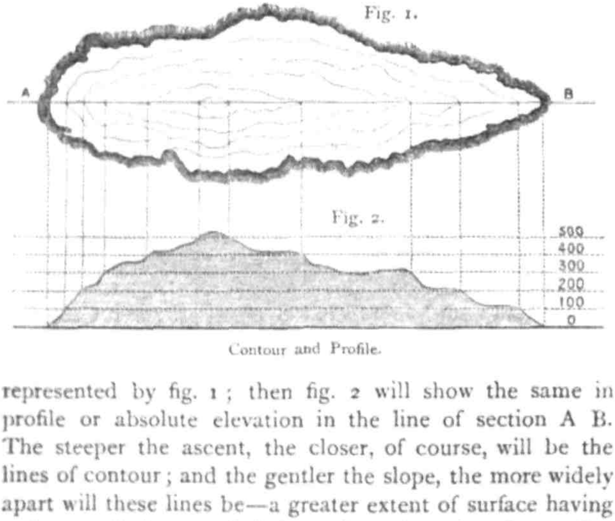
centre to centre, and in the alternate uprise and submergence of large tracts of the earth's crust, we behold the results of a definite and continuously operating law.

65. By *contour* is meant the outline or figure which the land receives by being surrounded by the water; and just as this outline is simple and uniform, or irregular and indented by seas, bays, and gulfs, so will its external conditions be varied, and its coasts worse or better fitted for the purposes of navigation and commerce. This contour depends mainly, of course, upon the original inequalities of the crust, but partly also upon the waste and degradation which all coast-lines suffer from the ceaseless action of the ocean. Combined, as in the case of Europe, with favourable relative position, it exercises most important influences on climate, productions, industry, enterprise, and civilisation.

66. By *vertical relief* is meant the elevation of the land above the level of the ocean; and just as this is regular or irregular, low or lofty, so will the whole character of a country be determined. A few hundred feet more or less of elevation would be sufficient to change the whole physical aspects of a country—converting arable fields and vineyards into pasture-lands, pasture-lands into pine-forests, and pine-forests into regions of glacier and everlasting snow.

67. Relative position, contour, and relief, being alike influential in modifying the external conditions of a region, the accuracy of their determination is of prime importance in all geographical descriptions. Latitude and longitude determine the position; a sufficient number of similar observations fix the contour; and trigonometrical survey or barometrical observation (mercurial or aneroid) can define the relief or outline of elevation. Position and contour are readily shown on maps by actual outline; relief can be indicated by a scale of shading, or, more accurately, by a system of contouring, as shown on Plate I. (Chartography) of the 'Physical Atlas.' Thus, taking the shore-line, which

is all necessarily on the same level being as the first contour, we may have similar lines taken at every 50 feet, or every 100 feet, of ascent, and these (when the observations are sufficiently numerous) will exhibit with great accuracy the risings and fallings of the surface configuration. Such a series of lines gives, as it were, the moulding or model of the surface, and a section of this model in any direction will show the *profile* for that direction. Suppose an island, for example, with its contours taken at every 100 feet of ascent, to be



Contour and Profile.

represented by fig. 1; then fig. 2 will show the same in profile or absolute elevation in the line of section A B. The steeper the ascent, the closer, of course, will be the lines of contour; and the gentler the slope, the more widely apart will these lines be—a greater extent of surface having to be travelled over. It is by such sections that the profiles of the different continents are usually shown, as will be more fully illustrated when we come to treat of the Mountains and Table-lands in the succeeding chapter.

VI.

THE LAND—ITS HIGHLANDS.

Mountains, their Characteristics and Origin.

68. HAVING directed attention to the general configuration of the land as dependent on its contour and relief, we now proceed to notice the special features of that relief as exhibited in its mountains and mountain-chains—its table-lands and plateaux. And first, of the mountains, which have long attracted the attention of geographers as one of the most obvious causes of climatic, vital, and political diversity. Defining a mountain as "any portion of the earth's crust rising considerably above the surrounding surface," it must be remembered that mountain-ranges are not mere *ridges* rising abruptly on one side and descending as abruptly on the other, but are in reality elevated tracts, often of great breadth as well as length, and consisting of rounded heights, lofty peaks, and boldly-escarped plateaux, with intervening valleys. As, *geographically* speaking, a mountain-range is not a single ridge of elevation, but a brotherhood of many elevations, so, *geologically* speaking, it is not a simple upheaval, the result of one paroxysmal outburst, or of one swift and sudden crushing together of its strata, but the work of innumerable volcanic outbursts, or of many slow and long-continued compressions, and subsequent denudations operating through many ages. A mountain-chain ten or twenty thousand feet in height and hundreds of miles in length, is thus a thing of slow and gradual growth — upheaval after upheaval, and eruption after eruption, contributing to augment the mass of final

accumulation. And as the times of contortion, upheaval, and accompanying volcanic action usually alternate with periods of comparative repose, gentle depression, and quiet deposition, we are able to judge of the relative ages of the formation of the several axes of mountain-ranges, by comparing the geologic dates of the contorted and disrupted strata out of which they are composed, with that of the gently sloping and undisturbed beds which repose upon their flanks, and say whether they were formed during primary, secondary, or tertiary eras. Again, by noting the direction of these axes of upheaval and the varying nature of the strata affected—whether consisting, on the one hand, of intractable granitiform, slaty, or schistose metamorphic rocks; or, on the other, of the comparatively soft and easily eroded sandy, shaly, and finely laminated beds of the fossiliferous systems—Geology enables Geography to account for the external characters of mountains, and to explain why some should be massive and rounded in outline, others serrated with splintery peaks and pinnacles—some conical and dome-shaped, and others again terraced by crags, and sloping away in long gentle declivities. It is in this way, also, that geologists speak of mountains of *upheaval*, of *accumulation*, and of *circumdenudation*,—meaning by the first, those which consist chiefly of upheaved strata; by the second, those formed mainly of volcanic eruptions; and by the third, those which consist of harder rocks (stratified or unstratified), that stand up while the softer materials which originally enveloped them have been worn and washed away.

69. Understanding the general character and formation of mountainous elevations, we may explain that the term *mountain* is usually applied to heights of more than 2000 feet—all beneath that height being regarded as *hills*, and those of still minor elevation as *hillocks*. A *mountain-chain* or *mountain-range* is a series of elevations having their bases in contact, and their axes or lines of elevations continuous over a considerable extent of country, as the Grampians, Urals, or Andes; a *group* consists of several ranges more or less connected; and a *system*, of several groups that evidently belong to the same set of geological operations. Mountain-summits are distinguished by such terms as *cones*, when gradually tapering to a point, as in volcanoes; *domes*, when more massive and rounded; *peaks*,

when abrupt and insulated; and by the French word *aiguilles*, or *needles*, when still more pointed, splintery, and detached. Their outlines or profiles are spoken of as *undulating*, *serrated*, *rugged*, and the like, as the case may be; and their sides are said to consist of *slopes*, *terraces*, *escarpments*, and *precipices*, or of a combination of these—such features depending partly upon their geological structure, and partly on the amount of waste and degradation to which they have been subjected. In general, mountain-ranges have a long, gentle declivity on one side, and a short and abrupt one on the other; and where this occurs, the longer declivity is spoken of as the *slope*, and the shorter one as the *counter-slope*. This slope and counter-slope is analogous to what in Britain is known as the "crag and tail"—most of our hills presenting a bold precipitous front to the west or north-west, and a long slope or tail to the east or south-east. The depressions and narrow valleys which occasionally intersect mountain-chains are known as *defiles* and *passes*; and these, offering, as they often do, the only means of transit across mountain-barriers, have ever been objects of political and commercial importance. Some of the most celebrated deeds in history are associated with these passes, and modern engineering is still in search of their easy gradients (Lat. *gradus*, a step), as affording facilities for highways and other means of communication.

70. With these explanations, the principal MOUNTAIN-SYSTEMS—whose direction and extent will be most conveniently seen by referring to the atlas, or to the sketch-map on page 76—may be here enumerated, the learner remembering that there is much in this arrangement that is arbitrary, or, at all events, not established by actual observation. Thus—

In EUROPE, geographers usually distinguish the *British System*, comprising the Grampian, Cheviot, Cumbrian, Cambrian, and Hibernian ranges; the *Iberian*, embracing the Pyrenees, the Cantabrian Mountains, the Sierra Morena, Sierra Nevada, and other ranges of the Spanish peninsula; the *Alpine*, including the Alps proper, Apennines, Carpathians, Balkan, and Hellenic ranges; the *Scandinavian*, or mountain-masses of Norway and Sweden; the *Sarmatian*, or central high ground of Russia; the *Uralian*, and *Caucasian*.

In ASIA we have the *Western System*, comprising the Taurus, Anti-Taurus, Lebanon, and Elburz ranges; the *South-eastern System*, embracing the Hindoo Koosh and Himalaya, and the mountains of Burmah, Siam, and Cochin-China; the *Eastern System*, comprising the Kuen-lun, the Pe-ling, Yung-ling, Kihan-shan, In-shan, and other Chinese ranges; and the *North-eastern System*, extending from the Bolor Tagh in the centre of the continent to Behring Strait, and comprehending the Thian-shan, the Altai, Yablonoi, and Stanovoi ranges.

In AFRICA, the *Atlas System*, between the shores of the Mediterranean and the Sahara; the *Guinea System*, embracing the Kong and Cameroon Mountains; so far as is known, the *Eastern System*, comprehending such as the Drakenberg, Lupata, and other contiguous ranges; and the *Cape System*, consisting of several parallel ranges, which increase in altitude from Cape Town to the interior.

In NORTH AMERICA, the *Pacific System*, better known as the Rocky Mountains, in the west; and the *Atlantic* or *Appalachian System* (Alleghanies, &c.) on the east. In SOUTH AMERICA there is the great system of the *Andes* on the west; the *Brazilian System* on the east; and the system of *Parimè*, between the rivers Amazon and Orinoco, on the north.

Of AUSTRALASIA and its mountain-chains we know too little as yet to enable us to arrange them into groups or systems, though one main ridge in Australia, extending along the eastern coast from Torres Strait on the north to the extreme point of Tasmania on the south, would seem to indicate a sameness and continuity of geological upheaval. New Zealand, in the middle island, exhibits a high, bold range on the west, whose summits (10,000 feet) are clad with snow, and whose glens are occupied by glaciers.

71. Besides the preceding, other minor systems have been named, but enough is here indicated to lead the learner to the appreciation of the fact, that the principal mountain-chains may be arranged in groups or systems that have arisen apparently from the same set of geological causes acting more or less continuously along the line or direction of their elevation. As mountain-systems exercise very decided influences on the natural history of the globe, and as they generally appear in ranges, consisting either of one central chain with branches or spurs running off at various

angles, or of several chains running less or more parallel to each other, various theories have been advanced to account for their upheaval, their parallelism, and their geographical connections. Thus, as their central masses were formerly supposed to consist almost exclusively of igneous rocks (see Atlas, Geological Map of Europe) which must have been protruded from below, and as this protruding force must have acted along the line of least resistance in the crust, the question arose, What is the determining cause of these directions? According to Elie de Beaumont, a French geologist, every system of mountains occupies a portion of a great circle of the globe—a cleft or fissure being more easily made in that direction than in any other; and he endeavoured to show that ranges of the same age are parallel to one another, even when in opposite hemispheres. Professor Hopkins of Cambridge, treating the subject from a purely mathematical point of view, has also shown that, when the upheaving forces act on a single point, the lines of upheaval must radiate from that point; hence lofty central mountains with diverging spurs. He further proved that, when the expansive force acts uniformly over a wide area, the lines of greatest tension or upheaval must be in the direction either of the length or of the breadth of that area, and that if the crust yields in more places than one, the fissures would necessarily be parallel. The more extended studies made of late years of the great mountain-ranges of the earth have, however, made it evident that their central parts are composed, not exclusively of igneous rocks, as formerly imagined, but of aqueous strata, greatly folded and compressed; the amount of compression being most intense along the axis of the range, and dying out towards the plains on both sides. This has led Professor Dana of Yale, and others, to refer the origin of all the grander mountain-chains to the elevation caused by the enormous lateral pressures developed in the gradual contraction of the earth's crust. Each broad subsiding area, as it descends towards the centre, occupies of necessity a less superficial space than before, and presses against the neighbouring areas with irresistible force, crushing and crumpling together the strata along the lines of contact, and forcing them upwards in a long mountain-chain.

Orography—Mountain Chains and Systems.

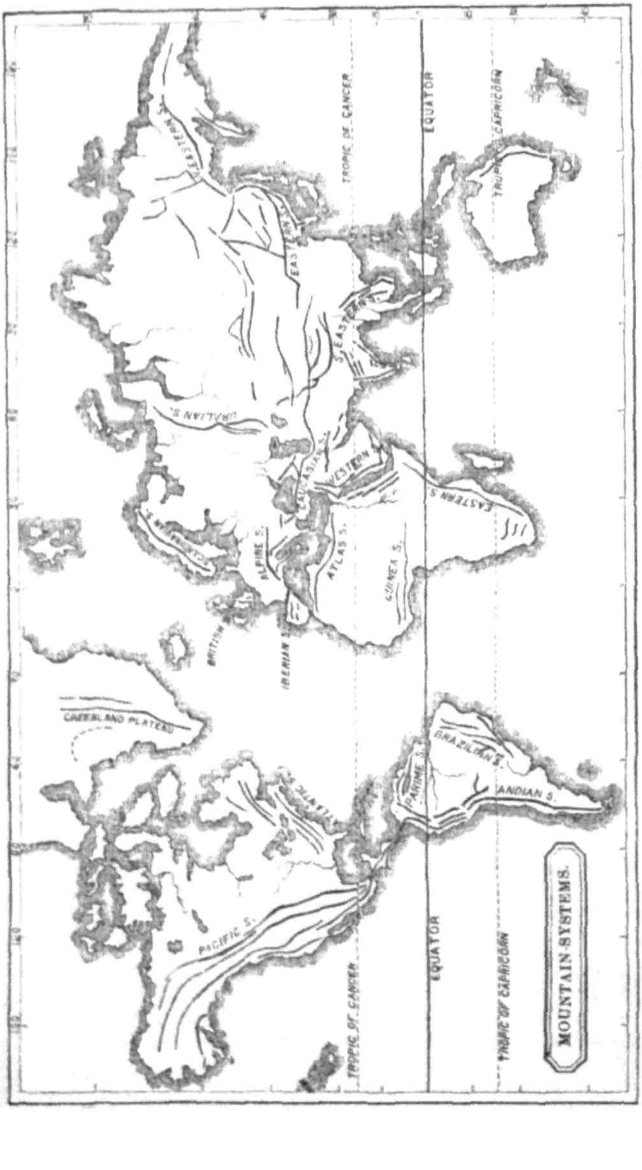
72. Accepting such generalisations as initiatory steps towards the explanation of one of the most important problems connected with the history of our planet, we may now briefly advert, under the title of *Orography* (Gr. *oros*, a height, and *graphé*, a description) to the character of the *mountain chains* or *ranges* of which the preceding systems are respectively composed. Under the *British System* are embraced the northern or Ross-shire range, the Grampians, the Cheviots, the Cumbrian or Cumberland mountains, the Cambrian or Welsh, the Devonian, and the Hibernian or Irish—all having less or more a south-west or north-east strike, and all formed of strata of the earlier or primary geological periods. Their geological structure—huge granitic bosses flanked and capped by the crystalline schists—confers on them considerable boldness and diversity of scenery, though their minor elevation prevents that massive grandeur and ruggedness so often displayed by loftier ranges. None of them rises to the height of perpetual congelation; but in an insular and northern situation like Britain, their cold, heath-clad, and inhospitable summits exercise a decided influence alike on the scenery, climate, and productions of the country.

73. The *Iberian* or *Hesperian System* embraces the Pyrenees, Cantabrian Mountains, mountains of Toledo, Sierra Nevada, Sierra Morena, and other associated elevations, that give character to the rocky table-land and peninsula of Spain. Less ancient than the British system, but loftier in their altitude and more extensive in their ranges, they exercise a still more decided influence on the external conditions of their region. Ranging chiefly in an east and west direction, and composed of rocks of primary and secondary formation, rising in many parts above the line of perpetual snow (which ascends from 8000 feet in the Pyrenees to 11,000 feet in the Sierra Nevada), and being intersected by numerous defiles, deep ravines, and circular valleys (*cirques* of the Pyrenees), they create great diversity of scenery, climate, and production, and are of themselves the frequent storehouses of the minerals and metals.

74. Under the *Alpine System* are usually comprehended the whole of those extensive and lofty mountains which,

from Switzerland as a centre, ramify in ranges more or less persistent, and confer on Southern Europe its distinctive and peculiar character. These ranges have many minor and local subdivisions, but for our present purpose it will be enough to arrange them into Eastern and Western Alps proper; the Gallo-Francian mountains, including the Jura, Vosges, &c.; the Apennines, traversing the entire peninsula of Italy; the Slavo-Hellenic, embracing the Herzegovina, Balkan, and Pindus chains, which lie between the Adriatic and the plain of the Danube; and the Hercynio-Carpathian range, which rises in rugged lines between the valley of the Danube and the great central plain of Europe. The strata upheaved in this grand Alpine system are of various geological ages—ranging from the granites and crystalline schists of the Western Alps, through the secondary limestones and altered shales of the Jura, to the tertiary beds of the sub-Apennines and the recent lavas and scoriæ of Vesuvius and Etna. Connected with the older range of the Pyrenees on the west, and with the still active cones of Vesuvius, Etna, and the Lipari Islands on the east, the Alpine system may be said to have been in process of development from the age of the Permian to the present moment—gaining accession after accession; and thus, even since the tertiary period, to much of the Apennine and Hellenic ranges, and to the Alps proper, an additional altitude has been given of not less, perhaps, than 4000 feet. Being of different geological structures and altitudes, the different members of the system present great diversity of character and aspect. Rising in many places above the snow-line, which sinks from 9000 feet in the Alps to 6000 feet in the Carpathians, they are rugged with peak and precipice, glacier and narrow gorge, as in the Alps—swelling and sloping in outline, as the Apennines—crateriform and terraced, as the hills of Auvergne—rocky and precipitous, as in the Pindus and Balkan ranges—or rich in mineral treasures, as the mountains of Transylvania.

75. The *Scandinavian System*, as the name implies, embraces the whole of the mountainous highland of Norway and Sweden, and extends, in a north-eastern direction, from the Naze to the North Cape—a distance of more than a thousand miles. It consists rather of a series of plateaux than of a continuous ridge; these mountain elevations



*** The heavy lines indicate the extent and direction of the principal Mountain-Systems usually defined by geographers.

(*fjelds*) narrowing from a breadth of 200 miles in the south to 60 or 40 in the north, and being distinguished as the Hardangar or Langefeld in the south, the Dovrefeld in the middle, and the Kœlen Mountains in the north. Intersected by numerous ravines and gorges, the range presents a steep face and rugged coast-line of fiords and precipices to the North Sea on the west, and a terraciform slope to the shores of the Baltic on the east. A great portion of the range rises above the limit of perpetual snow (which ascends from 2400 feet at the North Cape to 5000 feet in the Langefeld), but beneath that limit there is much of crag and forest. The whole consists of granitic, metamorphic, and palæozoic rocks, rich in minerals and metallic ores.

76. The *Sarmatian System* (from the ancient Sarmatia or Poland) is meant by geographers to embrace that swell of country which stretches diagonally through Russia from the plain of Poland to the Uralian Mountains, and which forms the long watershed of Northern Europe—turning the waters of the Vistula, Duna, Dwina, and Petchora to the Baltic and White Seas, and those of the Volga, Don, and Dnieper to the Caspian and Black Seas. There are no true mountains throughout its extent—the Valdai Hills attaining an elevation of only 1200 feet; but it forms a great watershed, and as such exercises considerable influence on the physical geography of Europe.

77. The *Uralian System* embraces the well-known range of the Ural Mountains, which form the natural boundary between Europe and Asia, and the watershed between the extensive basins of the Volga and Obi. Departing from the usual strike of the Old World mountains, the Urals run in a true meridional direction for more than 1600 miles, and consist of round-backed plateau-shaped masses of very moderate elevation, generally not exceeding 2000 feet, and culminating in a few points only at upwards of 6000 feet. The range consists of an axis of igneous rocks flanked by crystalline strata and the older palæozoic formations, and is rich in the precious minerals and metals.

78. The *Caucasian System*, which forms another part of the boundary between Europe and Asia, extends in one immense chain of 750 miles from the Black Sea to the Caspian, and separates the basins of the Kuban and Terek

on the north from those of the Kur and Rion on the south. The range is a bold and lofty one, full of glens and mountain fastnesses, and rises in many places above the snow-line, which there attains the altitude of 11,000 feet. The culminating point is Mount Elburz, near the centre of the chain; its height being 18,493 feet, or 2749 feet higher than Mont Blanc.

79. Turning next to Asia, which is the great headquarters of mountains and mountain-chains in the Old World, we may begin with the *Western System*, under which is comprised those numerous ranges that lie between the Levant and Black Sea on the west, and the Indus on the east, and give feature and character to the highlands of Asia Minor, Persia, and Afghanistan. Among these may be noticed the Taurus and Anti-Taurus, whose hilly and irregular ranges encircle the table-land of Turkey in Asia, and whose culminating point is Mount Argish, attaining a snow-clad elevation of not less than 13,000 feet. The Lebanon range proceeding transversely from the Taurus southward along the Syrian coast to Mount Hermon, 10,000 feet high, and thence through Palestine into the peninsula of Sinai, where Horeb, 8593, and Sinai, 7497 feet, may be said to terminate the chain. The mountains of Armenia, intimately associated with the Taurus and Anti-Taurus, are but prolongations of the same ranges, trending eastward into the Elburz, and southward into the Zagros and hills of Kurdistan—their culminating points being the snowy Ararat in Armenia, 17,210 feet, and the Sheikhiva, 10,120 feet, in Kurdistan. The Elburz range, a further prolongation of the Taurus and Armenian mountains, skirts the southern shores of the Caspian, where it attains, in the slumbering volcano of Demavend, an altitude of 14,675 feet, and thence stretches eastward into the Hindoo Koosh and mountains of Central Asia. The Hindoo Koosh or Hindoo Koh, separates Afghanistan and the Punjab from Independent Tartary, and forms the watershed between the Amoo and the Indus. Its maximum elevation is about 20,000 feet; and trending eastward in broad massive ridges into the Kuen-lun and Himalaya Mountains, it may be regarded as the commencement of the great central system of the Asiatic continent.

80. Closely connected with and following the Western is

the great *South-eastern System of Asia*, which comprises not only the highest mountains in that continent, but the highest known elevation on the surface of the globe. Pre-eminent in the system stands the chain of the Himalaya ("abode of snow"), stretching in a somewhat south-easterly direction between the basin of the Ganges and the upper basin of the Brahmapootra, forming the northern boundary of India, and constituting the southern buttress of the great central table-land. The range extends about 1500 miles in length, varies from 100 to 300 miles in breadth, and rises in many points (upwards of forty, it is said) to an altitude of 23,000 feet; the three highest points being Everest, Gahurishanka, or Deodunga, 29,002 feet — Kinchinjunga, 28,156 feet — and Dwhalagiri, 26,826 feet. The snow-line rises, according to geographical position in the range, from 13,000 to 16,000 feet; and a large portion being thus perpetually covered with ice and snow, the Himalayas present every possible feature of mountain grandeur—peak and precipice, gorge and glacier, rugged ravine and headlong waterfall. Some of the glaciers of the western range are the largest in the world—one in the Mustagh branch being 21 miles long, 24,000 feet above the sea in its upper portion; and in its lower portion, terminating in masses of ice 250 feet in height and three miles in breadth, is 16,000 above the level of the sea.

81. Abruptly separated from the Himalaya by the valley of the Brahmapootra, but still holding more or less in the same axial direction, are the mountains of Assam; and beyond these lie the well-defined ranges of Burmah, Siam, and Cochin-China—all trending in a southerly direction, separated by intervening river-valleys, and giving contour and character to the Cambodian and Malayan peninsulas. Little is known of these peninsular mountain-ranges, or of their elevations; but approaching the equator, we know that to great elevations they are covered with impenetrable forest-growth. Outlying the system, but still connected with the same area, are the mountains which give conformation to the triangular-shaped peninsula of Hindostan. These are the Vindhya chain, which forms, as it were, the northern barrier of the Deccan—the Western Ghauts, that support it on the west—and the Eastern Ghauts, that guard it on the east—the two latter chains converging into the loftier

heights of the Nilgherri Hills on its southern border. The plateaux of the Deccan rise, stage by stage, from 1500 feet in the north to 4000 or 5000 feet in the south; the Western Ghauts from 3000 to 5700 feet; the Eastern from 3000 to 4000 feet; and the Nilgherries in many points from 6000 to 7000 feet—attaining their culmination, 8760 feet, in the peak of Dodabetta.

82. Starting from the same central knot of the Bolor, and extending eastward to the Pacific, we have next what is termed the *Eastern System of Asia*, a series of vast and partially known ranges, associated with high desert table-lands in Tibet and Upper Tartary, and alternating with alluvial river-plains in the eastern districts of China. The system commences with the chain of the Kuen-lun, rising between the valleys of the upper Indus and Brahmapootra on the south, and those of the Amoor and Yarkhand on the north, and extending in an easterly direction for nearly 1200 miles, at an altitude of from 15,000 to 18,000 feet. Lying, as it does, in the same line with the Elburz on the west, and prolonged into the Pe-ling on the east, the whole looks like one great range, and is, no doubt, geologically dependent on the same axial elevation. Holding eastward, as we have said, into the main ridge of the Pe-ling Mountains, that rise between the basins of the Yang-tse-kiang and Hoang-ho, the system at the same time diverges, fan-like, into the Yun-ling chain, between Tibet and China; the Nan-ling, between the basins of the Yang-tse-kiang and Canton river; and the conjoint chains of the Ala-shan, In-shan, and Khingan, that trend in a north-easterly course, and form the southern wall of the great Mongolian desert. These several chains are said to be well wooded and rich in minerals and metals (jade, jet, kaolin, copper, silver, lead), but are little known.

83. Commencing in like manner with the central knot of the Bolor, and stretching away in broad, more or less parallel lines to Kamtchatka and Behring Strait, occurs the *Northern System of Asia*, flanked by the arid deserts of Tartary and Mongolia on the south, and descending by gradual stages to the great plain of Siberia in the north. The system embraces the Thian-shan or Celestial Mountains, ranging in an easterly direction for nearly 1400 miles, ascending in greater portion above the line of perpetual

snow, and exhibiting a number of cones of extinct volcanoes, some of which, like Pe-shan and Ho-tscheou, have an elevation of more than 10,000 feet. In north-easterly associations we have next the Altai Mountains, comprising several parallel ridges, the Daurian Mountains, and the Yablonoi Mountains, and other little-known ranges—all rising between Siberia and Mongolia, and separating the basin of the Amoor from those of the Yenesei and Lena. These closely associated ranges are said to have an average elevation of from 5000 to 8000 feet, embrace several active and many extinct volcanoes, rise high in numerous points above the snow-line, and culminate occasionally in peaks of 10,000 and 11,000 feet high. Still northward and eastward, but ramifying more irregularly, occur the Aldan, Stannovoi, and other chains that terminate in the volcanic system of Kamtchatka. These ranges are for the most part covered with snow (the snow-line sinking to 4500 and 4000 feet in Eastern Siberia), and contain numerous volcanic cones, which, like Schiwelutsch, 10,548 feet, and Klieutschewsk, 16,131 feet, are still in active eruption.

84. Of the African continent, to which we next turn, our knowledge is yet too limited to enable us to do more than merely advert to some of the more prominent mountain regions as likely belonging to separate and independent systems. In the extreme north we have the *Atlas System* rising between the Mediterranean seaboard and the Sahara, and extending from Tripoli on the east to the Atlantic on the west. Geologically, it is evidently connected with the systems of Southern Europe, and consists of three or four parallel ranges, which ascend stage by stage, from the basin of the Mediterranean, and increase in height from east to west—being about 2000 feet in Tripoli, 4500 in Tunis, 7700 in Algeria; while in Marocco, Mount Miltsin (Atlas) ascends to 11,400 feet, and Jebel Tedla to 13,000 feet, or above the line of perpetual congelation. Several secondary spurs proceed from the main ridges—one northward, and terminating in Cape Spartel, and several others southward into the desert plateaux of the Sahara.

85. Next in importance is the *Abyssinian System*, connected with and forming the lofty table-land (Amhara) of Abyssinia and Upper Ethiopia. This plateau, which is 7000 feet above the sea-level, is supported and traversed by

several clustering ranges of great elevation, and in many points above the line of perpetual snow, which is there about 14,000 feet. The two most persistent chains, under the names of the Samen and Taranta, strike in a northerly direction between the upper forks of the Nile and the Red Sea, and, skirting the shores of the latter, are prolonged into the lower hills of Egypt, which, at the Gulf of Suez, connect themselves with Sinai and the mountains of Syria. The culminating points in the Samen or upper range are Ras Detschen, 15,968 feet; Buahat, 15,000; Abba Jarret, 14,707; and Shubattai and Beyeda, each 12,000 feet. In the Taranta or lower range the heights descend from 9000 to 6000 and 5000 feet towards the Red Sea and the plain of Egypt.

86. In Western Africa the mountains are by no means well known; but under the *Guinea System* are usually embraced the Kong and Cameroon ranges—the former rising between the Gulf of Guinea and the Niger, and generally averaging from 1200 to 3000 feet (Soracte, 1278, and Mount Rennel, 3200 feet), and the latter stretching eastward and unknown into the centre of the continent, and rising in many points to elevations of 4000, 6000, 9000, and even 13,700 feet.

87. In Southern Africa the surface exhibits a series of sandstone plateaux, resting on and intersected by granitic rocks, rather than a series of well-defined mountain-chains—these flats (*karoos*) rising step by step from south to north at elevations of 2000, 4000, and 6000 feet above the sea-level. The steps of this ascent consist of rocky walls and flat-topped mountains, intersected by narrow gorges (*kloofs*) which form the only means of passage from terrace to terrace, and these mountains (*bergs*) may, for the sake of reference, be denominated the *Cape System*. The system consists, 1st, of the Zwellendam range, about 20 miles inland, stretching for nearly 200 miles in length, and attaining in Table Mountain an elevation of 3550 feet; 2d, the Zwarte or Black range, about 30 miles further northward, and separated from the Zwellendams by the Kannaland Karoo; and 3d, the northern chain, consisting of the Roggeveld, Nieuwveld, Winter Mountains, Sneeuwveld, Wittebergen, and other contiguous ranges, separated from Zwarte range by the Great Karoo, and attaining heights of 4000, 6000,

and even 8500 feet, as in the Compass Berg in the Sneeuwveld or Snowy range.

88. This Sneeuwveld or Snowy range passes insensibly to the north east of Cape Colony into what may be termed the *Eastern System*, consisting of the Drakenberg or Quothlamba Mountains (10,000 feet), the Lupata Mountains (8000 or 10,000 feet), and other partially known ranges, which hold northward in parallel lines and increasing altitudes towards the equator, where several of the higher peaks (Kenia and Kilimandjaro, 18,000 and 18,700 feet) are said to be covered with perpetual snow, and overlook the sources of the Nile and Congo; while others of inferior elevation, such as the ranges of Balegga and Lokinga, and the peak of Mfumbiro (10,000) are scattered irregularly through the strange lake-region between the Zambesi and the equator.

89. Of Australia and its mountain-chains it has been already stated (par. 70) that we know too little to enable us to arrange them into groups and systems, though one main ridge ("The Australian Alps"), extending along the eastern coast from Torres Strait on the north to the extreme point of Tasmania in the south, would seem to indicate a sameness and continuity of geological upheaval. This chain consists chiefly of granites and porphyries, intersected and overlaid in many places by recent volcanic products; is rich in metals (gold, tin, copper); is extremely rugged and inaccessible on the coast side, but slopes gradually towards the interior; and seldom exceeds 5000 feet in elevation,—Mount Kosciusko, 6500 feet, and Sea-View, 6000 feet, in Australia—and Mount Humboldt, 5502 feet, and Benlomond, 5010 feet, in Tasmania—being the highest known points of elevation.

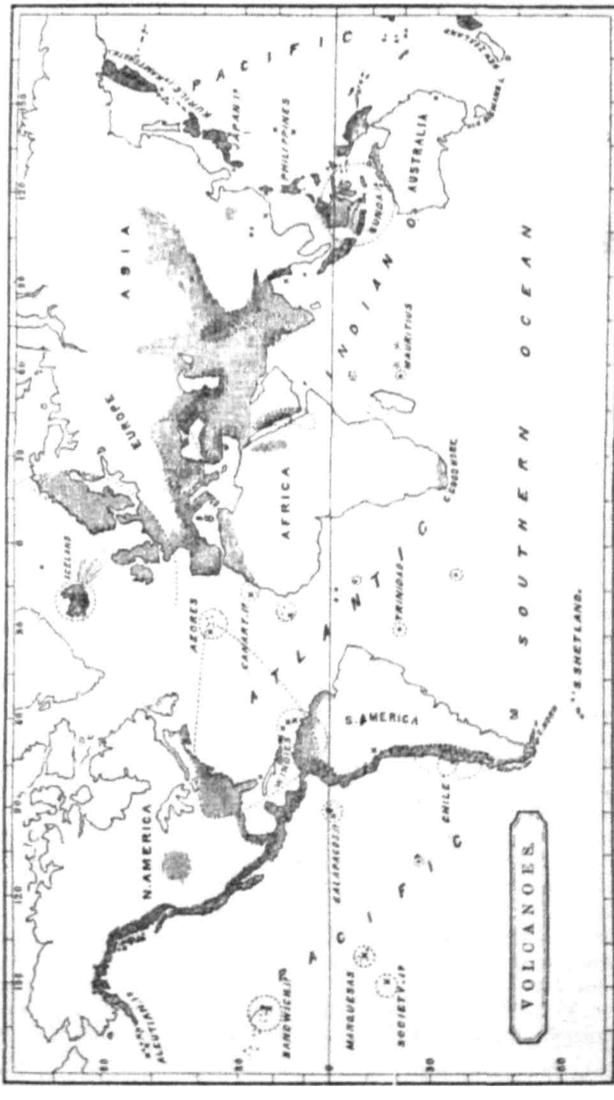
90. New Zealand contains one mountain-chain of considerable elevation—ranging north and south, and about 30 miles from the western coast. This great backbone is full of peaks and passes—the former often exceeding 10,000 feet in height, and the latter said to be practicable at elevations of 6000 and 8000 feet. Glaciers occupy many of the higher valleys, and send their ice-streams fully 13 miles down into the lower country. The culminating point of the system is Mount Cook, 13,200 feet high. The mountains on the eastern side are chiefly volcanic—Tongoriro, in

the north island being 6200 feet in height, and often in full activity.

91. Of the mountains that occur in the islands of the Pacific and the Indian Archipelago, it may be remarked that they are chiefly active volcanoes, and though often occurring in obvious linear connections, and of great altitudes (6000, 10,000, and 14,000 feet), they are merely to be regarded as chains in embryo, and the rudiments of systems yet to be elaborated. (For their dispositions and directions, see Map of Volcanoes, page 85.)

92. Having reviewed the mountain-systems of the Old World, we now turn to those of the New, where the arrangements are altogether on a simpler and more uniform plan. In North America we have first the *Eastern*, *Appalachian*, or *Atlantic System*, so called from its general proximity and parallelism to the Atlantic seaboard. It separates the waters that flow eastward into the Atlantic from those that flow westward into the basins of the Mississippi and St Lawrence; and though trending in one continuous direction from the Gulf States to the St Lawrence, may be said to consist of two main divisions—the Blue Ridge, Shenandoah Ridge, and Alleghany on the south, and the Green and White Mountains on the north, separated from each other by the narrow cross valley of the Hudson. In length the system is nearly 2000 miles, has an average breadth of 100 or 130 miles; and though its mean altitude is only about 2500 feet, it yet ascends in Mount Washington, in New Hampshire, to 6428 feet—in Black Mount, between Tennessee and Carolina, to 6476 feet—and in Mount Katahdin, in Maine, to 5360 feet. In the northern section of the system the ridges of the Notre Dame, the Green, White, and Adirondack Mountains are more or less irregular and interrupted; but in the southern, the Alleghanies consist of several closely parallel chains of great continuity, though frequently cut across by ravines and river-courses. Geologically, the system consists chiefly of the older or palæozoic rocks, flanked usually by an extensive development of carboniferous strata; and its eastern slopes comprise some of the finest and most diversified country in the American Union.

93. Interiorly, and beyond these eastern ranges, the country is one immense plain till we come to the *Western*



. The shaded portions indicate the *lines* and *centres* of volcanic activity; the more important volcanoes being marked by a ×.

or *Pacific System*, which, under the familiar name of the Rocky Mountains, stretches in unbroken ranges from the Isthmus of Panama to the shores of the Arctic Ocean. This extensive system, which, after all, is but the northern prolongation of the great backbone of the New World, consists of two main ridges—the Pacific or Oceanic, skirting the western seaboard from Cape Lucas in California to Cape Elizabeth in northern Aliaska; and the Rocky Mountains proper, extending in double, and sometimes in treble, chains from Panama to the Arctic shores. The former of these ranges forms the watershed between the Pacific on the west, and the Colorado, Columbia, and Colville on the east. Though continuous as one great range, it consists of several members, such as the Sierra de S. Lucia and Sierra Nevada in California, whose highest points are Mount St John, 8000 feet, and Mount Tsashti, 14,000 feet; the Cascade range in Oregon territory, culminating in Mounts Hood and Jefferson, 15,000 feet, and Mount St Helen's, 15,750 feet; and the Sea Alps in the north, having their highest points in Mount Fairweather, 14,783 feet, and the volcano Mount St Elias, 17,900 feet. Geologically, the range is of comparatively recent origin, contains many extinct and dormant volcanoes, and evidently connects itself with the still active series of the Aliaska peninsula and the Aleutian Islands. (See Map of Volcanoes, page 85). The latter or Rocky Mountain range forms, on the other hand, the long watershed between the tertiary valleys of the Colville, Fraser, Columbia, and Colorado on the west, and the great Lake region and the Plains of the Mississippi on the east. It consists, in like manner, of several members, which, though obeying the same axial direction, yet separate and converge so as to constitute a series of plateaux of varying magnitude and elevation. At the southern extremity of the range we have, first, the volcanic chain of Guatemala, rising in the craters of Atitlan and Agua to 12,500 and 15,000 feet; second, the clustering or transverse mountains of Anahuac or Southern Mexico, ascending in Orizaba and Popocatepetl to 17,337 and 17,884 feet; third, the Cordillera of Cohahuela, and Potosi, and the Sierra Verde and Madre, which support the lofty table-land of New Mexico, and ascend in Pike's Peak and Long's Peak to 10,000 and 12,000 feet; fourth, the

Wind River Mountains, &c., between Nebraska and Oregon, attaining in Holy Cross an elevation of 17,000 feet, Big Horn 15,000, Freemont's Peak 13,568 feet; and lastly, the northern and parallel ranges of the Rocky Mountains proper, which rise in Mount Lincoln to 14,300, in Mount Hooker to 15,700 feet, and in Mount Brown to 15,970 feet. Geologically, the whole of this vast range is of ancient formation, with the exception of the volcanic mountains of Guatemala and Mexico, and these are evidently portions of the still active development of Central America and the West India Islands.

94. In South America the pre-eminent system is that of *the Andes*, which extends along the Pacific seaboard from Tierra del Fuego on the south to the Isthmus of Panama on the north, there connecting itself with the onward prolongation of the Rocky Mountains. As a mountain-range, the Andes forms one of the most definite and persistent on the globe—skirting in unbroken ridges the entire Pacific shore for nearly 4500 miles in length, and varying in breadth from 40 to 350 miles. In some places the range consists of a single ridge—in other places of two or more ridges supporting lofty but narrow plateaux; and in general it presents a steep slope towards the Pacific, from which it is distant from 20 to 80 miles; while towards the east it descends by gradual stages into the broad plains of the Orinoco, Amazon, and La Plata. According to Humboldt, the mean elevation of the Andes is 11,830 feet, and the extent of surface covered by their bases not less than 531,000 geographical square miles. Geologically, the system is composed of metamorphic schists and palæozoic strata, pierced by granites, greenstones, and porphyries, but exhibits throughout a greater number of active craters (about 130) than any other mountain-chain, and, as a consequence, is largely crowned and covered, especially on its western slopes, by vast accumulations of lava, scoriæ, and other volcanic products. Though presenting one continuous axis, the range consists of several members, known by the countries in which they occur—as the Patagonian, the Chilian, the Bolivian, the Peruvian, and the Colombian Andes.

95. The Patagonian section consists of a single range of moderate elevation, but ascending in several points (Mount

Darwin, Mount Stokes, the volcanoes of Yanteles, and Minchinmadiva) to 6400 and 8030 feet. As the snow-line descends in southern Patagonia to 3000 feet, much of the range is perpetually frozen, and glaciers, unknown in other parts of the Andes, make their appearance in the higher glens and gorges. The Chilian Andes extend, in like manner, in one immense ridge; and though their mean elevation is inferior to those of Bolivia, they yet contain the giant Aconcagua—the culminating cone of the system, and the highest known point in the New World continent. The snow-line in this portion of the system rises from 8000 to 10,000 feet; and high above it in perpetual winter rise the lofty peaks of Aconcagua, 23,290 feet; Tupungata, 15,000 feet; and the volcanoes of Chillan and Villarica, 16,000 feet. Next in northward order occur the Andes of Bolivia, rising in two parallel ranges—the Cordillera of the Coast and the Cordillera Real—and supporting between them the table-land of Desaguedero, 13,000 feet above the sea, 500 miles in length, from 30 to 40 miles wide, and enclosing Lake Titicaca at an elevation of 12,846 feet. In this, the central portion of the system, the snow-line ascends from 15,000 to 18,000 feet; and high above it, in the western range, rise Sahama, 22,950 feet—Chiquibamba, 21,000—and the volcanoes of Gualatieri and Arequipa, 20,000 and 18,373 feet; and in the eastern range, Soracté, 21,286—Illimani, 21,140—and Cochabamba, 17,000 feet. Northwards from the Bolivian plateau, the Andes open up in three parallel ridges, known as the eastern, central, and western Cordilleras of Peru—the western being the highest, and separated from the Pacific by a sandy desert 120 miles in breadth. In these Cordilleras the highest points are Sasaguanca, in Lima, 17,904 feet; Vilcanota, 17,525; and the Knot of Pasco, 11,800 feet. Leaving the Cordilleras of Peru, we next meet, in northward order, the Colombian Andes, or the Andes of Quito—a lofty volcanic portion of the system, which rises in double or treble ridges, one main portion extending in the direction of Panama, and another bending north-eastward to the Caribbean Sea. In this region, much of which lies directly under the equator, the snow-line rises to 15,000 or 16,000 feet; and hence all the higher peaks and volcanoes—Chimborazo, 21,424; Cotopaxi, 19,500; Antisana, 19,132; Coyambe, 19,534;

and Tolima, 18,120 feet—are covered with perpetual snow. Such are the various portions that constitute the giant system of the Andes—a system which, whether in its extent and linear continuity, its boldness and altitude, its high inhabited table-lands, its mineral riches, or its physical influences, is, even more than the Himalayas, the most remarkable on the globe.

96. The system next in importance in South America is that of *Brazil*, occupying the eastern portion of the continent, extending in several parallel ranges from the plains of the Plata on the south to those of the Amazon on the north, and spreading inland for nearly 1800 miles in a broad plateau, whose mean elevation is about 3200 feet. These ranges or ridges of table-land are separated from each other by the affluents of the Amazon and the St Francisco on the one hand, and by those of the Paraguay and Parana on the other, and succeed each other, ridge and plain, with wonderful continuity. Proceeding from the Atlantic westward, we have first the Sierra Espinhaço, whose culminating heights are Itambe, 8428—Orgaos, 7700—Piedade, 5830—and Itacolumi, 5750 feet: and the Sierra do Mar or Sea-range, which attains in Morro dos Candos an elevation of 4476 feet: second, the Sierra Tabatinga, forking northward into the S. Irmaos and S. Mangabeiros: third, the Cordillera Grande, whose chief heights are from 6000 to 7000 feet; and lastly, the Sierra de los Vertentes and other inferior ridges, that gradually descend into the great central plain of the continent. Geologically, the Brazilian system is eminently primary, consisting of granitic protrusions and crystalline schists rich in the precious minerals and metals; abounding, from the character of its rocks, in picturesque beauty; and from its tropical situation and minor elevation, clothed to the summits with an exuberant and varied vegetation.

97. The last and only other mountain-system of South America is that of *Parimè*, which occupies the oval tract of country lying between the Amazon and Orinoco, and forms the high ground from which descend many of the minor affluents of these gigantic rivers. The plateau, whose mean elevation is from 1600 to 2000 feet, is traversed in an east and west direction by several closely-set ridges (Sierra Acarai, Parimè, Pacaraima, Imataca, &c.), which, though of no great general elevation, yet ascend in Duida to 7149 feet,

in Poraima to 7450, and in the Sierra of Merida to 15,000 feet. Like the mountains of Brazil, the system of Parimè consists of granitic bosses, crested and flanked by crystalline schists, and has not inaptly been described as a primary island rising from the vast tertiary and recent expanses of the Orinoco and Amazon. Lying almost directly under the equator, the higher sierras are clothed with impenetrable forest-growth; while the lower grounds, according to the seasons, are alternately arid wastes, or covered with a carpeting of the most luxuriant grasses.

98. Such are the principal mountains of the world—as arranged by geographers into groups and systems. The arrangement may not in every case be a natural one—that is, the mountains composing some so-called "system" may not strictly belong to the same set of geological causations—but the arrangement, such as it is, greatly facilitates reference, and aids our comprehension of the effects produced by any mountain-group on the climate and vital economy of the region in which it is situated. The arrangement has also its topographical advantages, for little can be done in the way of correct description till the objects to be described have been arranged and classified according to some principle of similarity or sameness of origin. But whatever may be the ultimate grouping, we see in mountain chains and systems one of the most important features in the physical machinery of the globe. Rising and falling—here in easy undulations, there in steep peaks and ridges—here in abrupt crags, and there in gentle slopes—they produce a diversity of surface eminently fitted for diversity of vegetable and animal life. Presenting their high ridges to the moisture-laden currents of the atmosphere, they serve as so many points of condensation, producing clouds, mists, and showers, that temper the heat in the lower regions, and refresh and nourish their vegetation. Elevated into regions of perpetual snow, in hot climates they cool the breezes that descend from their heights, while their snows and glaciers become perennial storehouses, which, under the summer sun, yield a copious supply to the streams and rivers of the thirsty lowlands. From their geological structure and formation, they are necessarily the chief repositories of the precious minerals and metals; and even such

deposits as occur in the sands and gravels of their streams have been worn and washed from their disintegrated veins. Their healthy, life-bracing heights have ever been the notable nursery-grounds of active, courageous, and independent races; while their snow-clad ridges become boundaries and barriers to nations, as well as to the dispersion of plants and animals, more impassable even than the breadths and depths of the ocean.

Table-Lands or Plateaux.

99. Next in importance, in the vertical relief of the land, are those elevated expanses known as ***table-lands*** and ***plateaux***. A table-land, as the name suggests, is a flat elevated surface; but this idea of flatness must be received only in a comparative sense, for the surface, though plain-like on the whole, is usually diversified by minor undulations and irregularities. Being in effect broad mountain-masses, these plateaux form the *gathering-grounds* and sources of some of the noblest rivers, while their elevation confers on them a climate and a vegetable and animal life distinct from that of the surrounding lowlands. They are inseparably associated with the mountain-systems, most of these systems not rising in narrow ridges from low-lying plains, but towering above broad elevated regions, which seem to be formed and supported by their bases. Thus, on turning to the map of Asia, it will be seen that all the great rivers flow north, south, east, and west from the central region, which consists in reality of a succession of lofty terraces or plateaux. First, we have the table-land of Iran or Persia (including large tracts of Beloochistan, Afghanistan, and Bokhara) rising from 3000 to 4000 feet above the sea-level, upwards of 300,000 square miles in area, and presenting throughout a riverless, parched, and desolate region. "Not only," says Mr Blanford in his 'Eastern Persia,' "is there no constant stream flowing from the interior of Persia, but no water-course communicates with the sea from the interior of the country, and every drop of rain which falls on the Persian plateaux is evaporated within its limits."

100. Next in altitude is the great sandy and rainless desert of Gobi, rising from 4000 to 6000 feet, and occupying an area of nearly 400,000 square miles; then rising on either

side of this, towards the centre, the plateaux of Dzungaria and Upper Tartary, less arid and more varied in surface; and lastly, the still loftier plateaux of Tibet—the highest inhabited region in the world, with an elevation of from 11,000 to 15,000 feet, and an area of 166,000 square miles. Besides these great central uplands, there are the lateral and more isolated plateaux of the Deccan, rising from 1600 to 2000 feet in Hyderabad, to 4000 feet and upwards in Mysore; of Arabia the sandy and arid, varying from 3000 to 6000 feet high, and spreading over an area of more than 700,000 square miles; of Armenia (7000 feet), supported by the Taurus and Anti-Taurus, and extending from the Dardanelles to the Caspian; and lastly, that of Ust Urt, between the Caspian and Aral Seas. With the exception of the Deccan, and the mountain-platforms of Armenia and Tibet, the whole of these table-lands, from Arabia on the west to Gobi or Shamó on the east, belong to one great belt of arid and rainless country, sandy and shingly in soil, desert in character, and evidently owing its origin to the same physical causes. Taking Central Arabia as typical of this broad desert belt, we find it graphically described by Mr Palgrave "as hard and stony in soil, with few sources of water rising to the surface even in winter; in spring thinly sprinkled with grass and herbs; in summer and autumn absolutely dry; and in general appearance level, monotonous, and desolate."

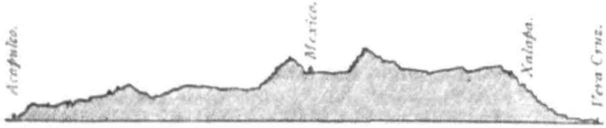
101. In Europe, less elevated and more broken up by seas, we have a smaller development of table-lands, and these generally of limited area, and in the southern division of the continent. The most notable is that of Castile in Spain, having an elevation of from 2000 to 2300 feet, and traversed by hilly ridges that give great irregularity and diversity to its surface. There is next the less defined upland of Switzerland, from 3000 to 4000 feet in elevation; and trending north-eastward, in the same direction, the lower plateaux of Bavaria and Bohemia, the latter having an elevation only of 900 or 950 feet above the sea. The so-called plateaux of Auvergne and the Scandinavian and Balkan chains, may be regarded as mere mountain-flats too limited in extent to possess any physical feature, or to exercise any influence distinct from those of their associated ranges.

102. Of Africa we have too scanty information to speak with certainty as to the plateaux and mountains that may rise within its interior; but we know that much of the Sahara or Great Desert is of the nature of an elevated table-land, but with a highly diversified surface (from 1500 to 2000 and 4000 feet); that inland from the coasts of Congo and Loango the country assumes the character of a lofty plateau; and that much of the equatorial region is so elevated (3000 and 4000 feet) as to enjoy the subdued climate of warm-temperate latitudes. There is also the plateau of Abyssinia (Amhara), 7000 feet above the sea-level, supported and traversed by several clustering mountain-ridges, which form the gathering-grounds of the Atbara, Blue Nile, and other rivers, which, during the rainy season, produce the fertilising inundations of Lower Egypt; and lastly, the *karoos* or terrace-plains of Southern Africa, rising stage by stage towards the interior to an elevation of 2000 feet—carpeted with grass during the rainy season, and parched and barren for the rest of the year.

103. In the New World the great superficial contrast is less between mountain and table-land or plain and elevated upland, than between the gigantic mountain-barrier that walls the Pacific from one extremity of the continent to the other, and the low broad plains that stretch eastward from its base towards the Atlantic. Nevertheless, in South America, the chain of the Andes presents several table-flats of vast elevation—the most remarkable being that of Bolivia, a great table-land 120,000 square miles in extent, rising from 11,000 to 12,500 feet above the sea, and early the seat of a busy and wealthy civilisation. Much also of the interior of Brazil partakes of the table-land character, having a mean elevation of 3000 feet, and traversed by the sierras (par. 96) that give feature to that fertile and tropical country.

104. In North America, from Aliaska on the North to Mexico on the south, there occur a series of elevated uplands, upborne, as it were, by the parallel ranges of the Rocky Mountains. One of the most remarkable of these plateaux is that comprising the highlands of Oregon and the saline desert or inland basin of Utah, whose elevation is from 4000 to 5000 feet, and the waters of which, having no outlet, form a series of salt lakes, one of which

(Utah) is of considerable extent, and almost saturated with salt. The most decided of the American table-lands, however, is that of Mexico, not more remarkable for its elevation than for its persistent extent. "On the eastern and western coasts," says M. Balbi, "are low countries, from which, on journeying into the interior, you immediately begin to ascend, climbing, to all appearance, a succession of lofty mountains. But the whole country is thus in fact raised into the air from 4000 to 6000 and 8000 feet. The conformation of the country has most important moral and physical results; for, while it gives to the table-land, on which the population is chiefly concentrated, a mild, temperate, and healthy climate, unknown in the burning and deadly tracts of low country into which a day's journey may carry the traveller, it also shuts out the former from an easy communication with the sea, and thus deprives it of a ready access to a market for its agricultural productions." As



Mexican Table-Land.

with the Mexican table-land, so in fact with all others of any decided elevation. A distant island in the ocean is not more separated from its contiguous continent, or more strongly marked by its own physical peculiarities, than a high mountain-walled tract raised several thousand feet into the atmosphere is characterised by a climate and vegetable and animal productions unknown in the regions that surround it.

RECAPITULATION.

105. In the preceding chapter attention has been directed to the more elevated portions of the Land, as consisting of mountains and table-lands. These mountains have been arranged by geographers into *chains* and *ranges;* and these ranges, again, into *groups* and *systems* that occupy the same

contiguous area, and apparently belong to the same series of geological operations. The continuity of mountain-chains has been observed from the earliest times, and hence the antiquity of the names by which many of them are distinguished; but their classification into groups and systems is of recent date, and liable to correction and amendment as clearer and more correct views are obtained respecting the forces on which their formation and elevation depend. In the meantime, and for the sake of reference, the mountains of Europe have been arranged into the British, Iberian, Alpine, Scandinavian, Uralian, and Caucasian systems; those of Asia into the Western, South-eastern, Eastern and North-eastern; and those of Africa into the Atlas, Abyssinian, Guinea, Cape, and Eastern systems. In the New World the mountains of North America are usually arranged into the Eastern or Atlantic system, and the Western or Pacific; while those of South America are distinguished as the systems of the Andes, or Parimè, and of Brazil. As to the table-lands, the more important and better known in the Old World are those of Castile, Switzerland, Bavaria, and Bohemia, in Europe; and of Armenia, Arabia, Persia, Tartary, Mongolia, Tibet, and the Deccan, in Asia. In the New World, those of Bolivia and Brazil are the most notable in South America; while in North America the only similar tracts deserving of notice are the table-land of Mexico and the desert uplands of Utah and Oregon. In whatever form the highlands of the globe appear, whether as linear mountain-chains or as broad-spreading plateaux, they exercise most important influences on climate, and consequently on the distribution of plants and animals. In the torrid zone they afford the climate and produce of temperate regions, and in temperate zones they assume the characteristics of polar latitudes; while everywhere they are the great gathering-grounds of glacier, stream, and river—dispensing their stores to the thirsty lowlands in moderated but never-failing supplies.

VII.

THE LAND—ITS LOWLANDS.

Plains and Deserts.

106. As the higher and more irregular portions of the earth's surface consist of mountains and table-lands, so the lower and more level consist of plains and valleys. The one set of features counterbalances as it were the other, and thus contributes to that variety of aspect so pleasing in the landscape, and so indispensable to diversity in its vegetable and animal productions. Though the term *plain* is usually applied to level expanses of no great elevation, and is apt to be associated with ideas of verdure and fertility, yet several of the great plains of the world are considerably above the sea-level, and present every variety of surface, from green grassy flats to deserts of shingle and loose shifting sand. In general terms the "lowlands" of the world may be regarded as lying at elevations under 500 or 400 feet—all above these heights taking rank as "uplands" or "plateaux," or passing into the still loftier altitude of "mountains" and "mountain-ranges." As mountains are the results of upheaval, continued through indefinite ages, so plains are the less disturbed portions of the earth's crust, and, in several instances, represent the beds of former seas, and the silted-up sites of lakes and estuaries. Not only does their general contour convey this impression, but their soil and subsoil usually reveal their origin, and point to a time when large expanses of water occupied the areas of the present plains, and shallow estuaries and chains of lakes the sites of our alluvial valleys. Bearing in mind this origin, it will help to

explain certain appearances of soil and surface, and enable us to account for certain distributions of plants and animals that might otherwise remain inexplicable.

107. In treating of the low level tracts of the Land, the terms *plain* and *valley* are sufficiently general and well understood, and are therefore the most frequently employed in geographical description. There are others, however, which refer either to some peculiarity of surface and condition, or are of local origin, and these it may be useful at this stage to explain. Thus, the term *prairie*, though simply the French word for "meadow," is usually applied in a technical sense to the open, slightly undulating, grassy plains of North America — and *savannah*, to the grassy and more fertile portions along the Atlantic; *llanos* are the river-plains of tropical South America alternately covered with rank vegetation, and reduced to a desert by periodical droughts; *selvas* (Lat. *silva*, a wood), the higher tracts of the same region densely covered with forest-growth; and *pampas*, the treeless but grassy plains of the Parana and La Plata. The term *steppes* is applied to the plains of northern Asia generally covered with long rough grass, but also partially wooded, and not unfrequently shingly and desert; *tundras*, to the boggy flats of Siberia and northern Russia; and *tarai*, to the belt of unwholesome jungle that lies between the plain of Hindostan and the Himalayas. *Sahara* is the long-established and familiar name for the great arid and sandy desert of northern Africa; while *karoo* is applied to the open flats in the southern region of the same continent, which are hard and arid in the dry season, but carpeted with grasses and flowers during the periodical rains. In Britain, the terms *dale* and *vale* are usually applied to minor river-plains; *strath*, in Scotland, to any wide stretch of generally flat-lying land; and *carse*, to those level alluvial flats (*levels*, in England) that occur in connection with existing estuaries,

Delta of the Nile.

and which have evidently been reclaimed from their waters either by the ordinary process of silting, or by partial upheaval of the land. The term *delta* is also largely applied to the alluvial land formed at the mouth or rather *mouths* of a river, such as that of the Nile, which first received this name from the resemblance that the triangular space enclosed by its two main mouths bears to the Greek letter Δ or delta. Other terms than the above are still more local and restricted in their application, and will be better explained in the text as they happen to occur.

108. The principal plain in the Old World is that usually known to geographers as the *Great Northern Plain*. It may be roughly sketched as commencing with the shores of Holland on the west, and extending eastwards through Prussia, Poland, Russia, and Siberia, without any very marked interruption save the intersecting range of the Uralian Mountains. "Take away the Ural," says Carl Ritter, "and a continuous line could be drawn from Bredo, near the confluence of the Meuse, Rhine, and Scheldt, across Europe and Asia, following the line of 50° N. lat., as far as the Chinese frontier, passing over a continuous series of low insignificant hills, heath-lands, and steppes, and traversing a space estimated by Humboldt to be three times the length of the Amazon!" In width this great lowland stretches from the shores of the Arctic Ocean almost to the base of the Carpathians in Europe, and to the table-land of Persia and the flanks of the Altai Mountains in Asia—thus occupying between 4,000,000 and 5,000,000 square miles, or nearly one-third of the entire area of these continents. While it slowly rises from the Arctic shores towards the interior, as may be seen by the courses of all the great northern rivers, it may be traversed from east to west (if we except the Uralian range) without changing the level more than three or four hundred feet. In Europe, this vast expanse is usually subdivided into the *Germanic Plain* on the west, and the *Sarmatian Plain* on the east; while in Asia it comprises the *Steppes of Kirghis, Ishim*, and *Baraba* on the west, and the *Siberian Plain* on the north and east. Each of these subdivisions is necessarily characterised by its own peculiarities of soil, situation, and climate. Thus the Germanic section includes the low-lying polders and morasses of Holland, and the sandy boulder-strewn plains of Northern Germany

and Prussia—partly under cultivation, and partly occupied by heath and open pasture. The Sarmatian section, on the other hand, consists of cold, swampy, and partially wooded flats in the north; of moderately temperate, fertile, richly wooded, and undulating tracts in the middle; and of indifferent grassy steppes and saline deserts in the south. The steppes of Kirghis, Ishim, and Baraba present, as the name implies, wide monotonous tracts covered with rough grass and shrubs during a brief season, but soon converted into arid deserts by the drought of summer, and into bleak, shelterless wastes by the storms of winter. The *Siberian Plain*, as might be expected from its extent, is of a more varied character—consisting of low-lying tundras or earthy peat-mosses, of broad, undulating steppes, and partially wooded uplands. In summer the tundras are thawed to a small depth, the steppes are scantily covered with grass and mosses, and the banks of the great rivers and uplands are green with the birch and pine; but during the long winter, frost and snow reign supreme, and the whole plain is one dreary and inhospitable wilderness.

109. The secondary plains of the Old World, though of minor extent, are not without their decided influences on the physical and vital phenomena of their respective continents. Among those in Europe may be noticed the *plain of France*, comprising the conjoined low grounds of the Seine, Loire, and Garonne; the basin-shaped *plain of Hungary*, watered by the Theiss and Danube, and sometimes spoken of as the "European Pampas;" the *plain of Wallachia* on the lower Danube; the *steppe of Astrakhan*, lying along the Caspian and Volga; and the still more restricted plains of Ireland, Denmark, Andalusia, and Lombardy. Among the secondary plains in Asia may be noticed those of China, Hindostan, Turan, and the Euphrates. The great *river-plain of China*, said to occupy nearly 200,000 square miles, is alluvial throughout, and still rapidly on the increase by the silting-up of the Yellow Sea, is crossed in every direction and irrigated by canals, and is the fertile seat of one of the oldest, most industrious, and most numerous populations on the face of the globe. The *plain of Hindostan*, stretching from the base of the Himalaya to the Deccan, and from the Indus to the Ganges, is also low-lying and alluvial, abundantly fertile under irrigation, and only light

and sandy in the district of "the Thur," on the lower Indus. The *plain* or *steppe of Turan* extends along the southern shores of Lake Aral westward to the Caspian, while the historic *plain of Mesopotamia* (Gr. *mesos* and *potamos*, between or in the middle of the rivers) stretches between the Euphrates and the Tigris southwards to the Persian Gulf.

110. In Africa, with the exception of the *Sahara* or *Great Desert*, which may be described as a vast expanse of arid sands and shingle, with an occasional oasis of life and verdure, we know of no continuous plains like those of Europe and Asia, though several minor flats and deltas give diversity to its generally unbroken and monotonous seaboard. The surface of the Sahara is not, however, as at one time supposed, a uniform plain of burning and drifting sands, but presents considerable diversity both in composition and altitude. Some portions are low and flat; others sink, it is said, even below the sea-level; while many rise in bare, broad plateaux 1000, 2000, and 3000 feet above the surrounding surface. Immense tracts are shingly and saline, as if the desiccated bed of a former sea; others consist of loose drifting sand; occasional patches are rocky, and scantily covered with thorny scrub; while, at distant intervals over the arid waste, some spring or surface retention of water gives birth to an *oasis* or islet of vegetation. [This great desert, stretching from Marocco on the west to the valley of the Nile on the east, is prolonged, as it were, eastward and northward through Arabia, Persia, and Tartary to Mongolia, where it terminates in the equally arid and sandy desert of Shamo—the whole tract from the Sahara to Shamo pointing at once to similarity of conditions and sameness of physical origin. It is the rainless region of the Old World, with no moisture to give its soil coherence, destined to sterility, and traversed by sand-storms (see Map of Rainfall).] The minor low-grounds of Africa, sufficiently known to geographers, are those on the lower courses of the Senegal and Gambia—Senegambia; the swampy and jungly delta of the Niger; the fertile, periodically inundated delta and valley of the Nile; and much of the swampy and wooded tracts that surround or alternate with the lakes and rivers recently indicated by Cameron and Stanley south of the equator.

111. Respecting Australia—the only other region in the Old World sufficiently extensive to admit of plain-lands—we are yet too scantily informed to offer any definite opinion as to the nature of the interior, though recent discovery would seem to indicate that, instead of a vast scrubby and waterless plain, there is much practicable country—grassy flats, gum-forests, and river-creeks, marking, at intervals, the routes of the adventurous explorers.

112. Turning next to the New World, we find the plains on a much more conspicuous and decided scale—stretching more continuously, and rising less above the level of the ocean. In North America, the *Great Central Plain*, lying between the Rocky Mountains on the west and the Alleghanies on the east, extends, it may be said, from the Arctic Ocean to the Gulf of Mexico, a distance of nearly 3000 miles. Throughout this long course it is only once interrupted by the gently swelling prairie-grounds (1500 or 1600 feet in height) that turn the courses of the Red and other rivers to the north, and those of the Missouri and Mississippi to the south. Varying, in wide expanses, from 100 to 600 and 800 feet in elevation, it presents considerable diversity of surface—swampy marsh, grassy prairie, forest-land, and barren ground. The most notable feature in the surface of this great central plain, which occupies an area of nearly 3,000,000 square miles, and has been characterised by Humboldt as "an almost continuous region of savannahs and prairies," is undoubtedly that of the open, slightly undulating, and grassy portions denominated *prairies*. These prairies are of vast extent; some are rolling, others are flat and level in surface; many of them are treeless, and covered only with luxuriant grass and flowers; towards the south some tracts verge into shrubby woodland, while in the extreme north the soil is largely swampy and desert. The only other notable lowland in North America is the *Atlantic Plain*, lying between the Alleghanies and the Atlantic—a fertile district of little elevation, but often flat and swampy, along the seaboard.

113. In South America we are presented with three well-marked and distinctive river-plains—viz., those of the Orinoco, the Amazon, and La Plata. The first is one of the lowest and most level tracts in the world, rising not more than 200 feet at the distance of 500 miles from the

sea, and throughout that course marked by swamps, periodically overflowed grass-flats (*llanos*), and tropical forest-growths. The llanos occupy an area of about 160,000 square miles, which is almost wholly inundated during the rainy season, but shortly afterwards is so densely covered with luxuriant grasses that it is known to the natives as the "sea of grass." During the ensuing tropical droughts these llanos become parched and withered; hence the frequent conflagrations to which they are subject; and hence also, to a great extent, the perpetuation of their treeless character. The second or Amazonian plain, still more extensive and unique, is characterised by similar forest-growths (*selvas*) and grassy plains, and is the largest river-basin in the world, occupying an area of about 1,500,000 square miles. Richly alluvial in soil, periodically inundated, and under the influences of a tropical sun, these *selvas* present the rankest luxuriance of primeval forest-growth, and are in many places accessible only by the river-courses that traverse their areas. And yet, though rich in vegetation, it is, according to Mr Orton in his 'Amazon and the Andes,' the most thinly inhabited region on the globe, there being not above 40,000 souls along the banks of the river in the whole province of Amazonas and lower Marañon. Vegetation has the mastery, and the battle for existence leaves little chance for animal life. The third plain, comprising the basins of the Uruguay, Parana, La Plata, and Colorado, embraces an area of not less than 880,000 square miles, and is characterised chiefly by its deep alluvial soil, broad thistly flats, and grassy pastures, known as *pampas*. Stretching from the flanks of the Andes to the shores of Buenos Ayres, and thence southwards to the deserts of Patagonia, these pampas differ considerably in character, being flat and thistly towards the coast, slightly undulating and grassy towards the interior, and full of bogs and swamps and scrubby ridges as we approach the Andes. The whole region is treeless, verdant during the rains, but withered and parched during the dry season. The desert terrace-land or steppes of Patagonia, extending southward from the Rio Colorado to the extremity of the continent, is a sterile uninviting region—the soil shingly and strewn with boulders, the grass stunted, and the climate cold and tempestuous.

Valleys and Minor Depressions.

114. Besides the great plains of the world, there are numerous valleys and minor low-lying tracts that exercise a decided influence on the soil, climate, vegetables, and animals of the countries in which they occur. These are the *dales* and *vales* of existing streams, the broader *basins* of lakes and rivers, and the *straths*, *carses*, and *deltas* of our estuaries. Whether they have been formed by subsidences of the earth's crust, by the silting-up and drainage of lakes and morasses, or by the slow, erosive power of rivers (valleys of erosion), their characters are much alike, and the purposes they subserve identical. Their low-lying situations, their tempered climates, their rich soils, and well-watered surfaces, have ever made them the grand nurseries of vegetable and animal growth; and this fertility and amenity has ever attracted the human race, and rendered them the main theatres of industry and civilisation. To particularise the lesser valleys—the dales and vales that give amenity and richness to the land surface—would be merely to enumerate the rivers and streams that flow through the different continents. Every stream has, in some part or other of its course, its strip or patch of valley ground: and these occur of every extent, from the meadow of a few acres to the dale of many leagues; at all altitudes, from the polder and fen protected from the tides by embankments, to the valley high among the mountains; and in every variety of surface—morass, silt, sand, gravel—from the warp of the latest flood to the greensward of a thousand centuries. In civilised countries these lowlands are the principal seats of culture and husbandry; while in semi-civilised regions they constitute the pasture-lands of the nomadic shepherd and herdsman.

115. Besides the dales and vales and valleys properly so called, there are also the *deltas* of many rivers—low-lying tracts still in course of formation, and which, from their swampy and partially inundated character, can scarcely be said to belong to the domain of the land. To this category belongs much of the deltas of the Niger and Nile, the Indus, Ganges, and Irawaddy, the Mississippi, and the Orinoco

and Amazon. The older and higher portions of those deltas have long since been converted into fertile alluvial plains; but the lower portions consist largely of mud-flats, sandbanks, and lagoons, partially covered with jungle-growth during the dry season, yet inundated as far as the eye can reach during the periodical overflows of their rivers. In course of time the existing mud-flats and sandbanks will be converted into alluvial land, and other banks and shoals will arise as the sediments of the rivers are carried further forward into the area of the ocean. Besides the river-deltas, there are also considerable low-lying tracts of marine silt and sand-drift formed, and still forming, along many of the more sheltered bays and recesses of the ocean. These, like the *links* of our own islands, the *landes* of France, the *dunes* of Holland and Denmark, the *fens* of England, and the *swamps* of Florida, are gradually on the increase, and in process of time assume a flat or plain-like surface.

116. As there are plains and valleys at considerable elevations, and others again scarcely raised above the overflow of the tides, so there are several areas depressed even beneath the general level of the ocean. Laying aside some tracts of the Sahara or Great Desert of Africa, which are known to sink beneath the sea-level, the most remarkable of these ascertained depressions are the Aralo-Caspian basin and the trough of the Dead Sea. The former of these, in which are situated the Caspian and Aral Seas, is a depression of 162,000 square miles in extent, all considerably below the ocean—the surface of the Caspian, the lowest portion of the cavity, being actually 83 feet beneath the level of the Black Sea. The latter, though a mere trough in comparison with the former, is still more remarkable for its depression, the Dead Sea being not less than from 1290 to 1298 feet (according to the season of the year) below the level of the Mediterranean, from which it is separated by the mountain-range of the Lebanon. Were it not that the river-supply of these cavities is fully counterbalanced by evaporation, they would, in process of time, become filled with water, and their surplus find an outlet to the ocean—the Aral and Caspian to the Euxine, and the Dead Sea to the Gulf of Akaba in the Red Sea, with which at some former period it was evidently connected by the dry stony valleys or "wadies" that now lie between.

RECAPITULATION.

117. In the two preceding chapters we have endeavoured to present an outline of the superficial features of the land, as composed of mountains and table-lands, of plains and valleys, and the relations they bear to each other in the scheme of Physical Geography. Whatever be the geological law that regulates the successive upheavals and submergences of large tracts of the earth's crust, we see in the arrangement of the present continents the more violent effects of the earthquake and volcano in producing abrupt and mountainous irregularities, and the more gradual efforts of air and water in moulding into uniformity of surface its plains and valleys. Whatever be the nature of the vulcanism acting from within, we see that it exerts itself in certain definite lines and centres, and these lines and centres give rise to mountain chains and groups, and these again give contour and configuration to the terrestrial areas. In the Old World, as already stated, the main axis of elevation is from east to west; hence the greatest length of the continent in this direction, and hence also the determination of the rivers and river-plains in northerly and southerly courses from this axis. In the New World, again, the main line of elevation is from south to north; hence also the corresponding direction of that continent, and the opposite courses of its principal rivers.

118. As with the main continental masses, so with the minor spurs and peninsulas — their direction of greatest length being invariably regulated by the direction of their hills. Geology thus becomes the evident groundwork of Geography; and on reference, for instance, to the Geological Map of Europe (Plate II. of Johnston's 'Physical Atlas'), it will be seen that the granitic, trappean, and volcanic outbursts are all related more or less to the

extent and directions of the mountains of that continent. As the great plains are but the undisturbed portions of the continents, they will naturally take the same main direction as the mountain-ranges; just as the table-lands, which are upraised by the mountains, will be situated among their groups or along their axes. On the other hand, the rivers, obeying the laws of descent from the opposite sides of these axes, will have their valleys and dales running less or more in cross courses, thus giving additional features of diversity to the land. In the Old World the principal mountain-chains are those of the Pyrenees, Alps, Carpathians, Caucasus, Himalayas, Thian-shan, and Altai, which trend in one main direction from the Atlantic on the west to Behring Strait on the east; and this great irregular axis is flanked on the north by the plains of Central Europe and Siberia, and on the south by the minor plains of Hindostan and China. In the same manner, in the New World, the Rocky Mountains and Alleghanies alternate with the central and Atlantic plains of North America; while in South America the great lowland may be said to stretch between the Andes and the Cordilleras of Brazil, the only exception being the river-valley of the lower Amazon.

119. Mountains and table-lands, plains and valleys, are thus but the counterparts of each other; and rugged and inhospitable as the former may seem, the latter would be but thirsty deserts were it not for the clouds and rains, the streams and rivers that are generated among their summits, and descend in perennial supplies from their glens and recesses. Ethnologically, as mountain regions have ever been the nursing-fields of hardy, brave, and independent races, so plains and valleys have ever become the sheltered and fertile seats of settled industry and civilisation. The plains of China and Hindostan, of the Tigris, the Euphrates, and the Nile, were the early and populous abodes of mankind in the eastern hemisphere, just as in the

western the valleys of the Missouri and the Mississippi were the chosen grounds of primitive mound-building races. And as in former ages, so even now the principal sites and centres of industry are to be found in the river-plains of the Old and New Worlds—the causes that induced the early shepherd settlers being equally operative on their agricultural, city-dwelling, mechanical, and commercial descendants.

narrow interstices, in which it rises slightly above the general level by the attraction of the sides; and this *capillarity* is of essential service in disseminating moisture through the pores of soil and rock, and it may be through the tissues of the vegetable kingdom. As an agent in nature, water is indispensable to the life of plants and animals; it enters into the composition of all bodies, whether organic or inorganic; and in the form of rain, rivers, waves, tides, and ocean-currents, is the great modifier and remodeller of the geological aspects of the globe.

122. It has already been noticed (chap. iv.), that though encircling the globe on every side, and spreading over nearly three-fourths of its surface, the great "world of waters" is more or less configured into certain expanses which are termed *oceans;* and thus we have on the west of the Old World, and between it and the New, the *Atlantic* Ocean; while on the west of the New World, and between it and the Old, spreads out the still vaster area of the *Pacific*. These divisions become apparent on the most cursory inspection of the map of the world—the former lying like an irregular valley between the two continental land-masses, and communicating freely with the arctic and antarctic waters; the latter narrowed to a mere strait on the north, but spreading out towards the south over nearly half the globe, and ultimately losing its individuality in the undefined expanse of antarctic waters. Besides the Atlantic and Pacific, the *Arctic* and *Antarctic* constitute well-recognised though imperfectly known oceans; while between Africa and Australasia stretches the familiar and much-traversed area of the *Indian* Ocean. In treating of these great oceanic expanses, various names and subdivisions are employed by navigators; but for all practical purposes in Physical Geography the terms North and South Atlantic, North and South Pacific, Arctic, Antarctic, and Indian Oceans, are sufficiently explicit and comprehensive. Or, looking upon the waters that extend southwards from the extreme points of Africa, Australia, and South America as one great united mass, the term *Southern Ocean* will often be found to be convenient, and not inappropriate.

123. Taking the Atlantic Ocean as extending from the arctic to the antarctic circle, its length is upwards of 9000 miles; its breadth varies from 900 to 4000 miles, being

only 900 between Norway and Greenland, 1700 between Sierra Leone and Brazil, and 4100 between Marocco and Florida; and its computed area is about 25,000,000 square miles. This vast expanse is little interrupted by islands. In its northern section it is irregular in form, and throws several important branches into the land; but in the southern its form is regular, and its shores continuous. Towards the north it is partly enclosed by the rocky coasts of Greenland, Iceland, and Norway; but towards the south it is quite open, and merges broadly into the Antarctic Ocean. The leading branches are Baffin and Hudson Bays, the Gulf of St Lawrence, Bay of Fundy, Gulf of Mexico, and the Caribbean Sea, on the west or American side; and on the east or Old World side, the North Sea, Baltic Sea, English Channel, Bay of Biscay, the Mediterranean Sea, and the Gulf of Guinea. All, or nearly all, of these recesses occur in the northern division of the Atlantic; hence the greater interest of this section to the geographer, naturalist, and navigator. Of the minor seas (some of which are ice-locked for a considerable portion of the year, and others encumbered by reefs and shoals), the most important, physically and vitally, is the Mediterranean, whose shores formed the early nurseries of civilisation and commerce, and whose waters are still the highway of communication, not merely between the three continents—Europe, Asia, and Africa—that encircle its shores, but between these and every other portion of the globe.

124. The Pacific Ocean, though less important as a highway of commerce, occupies nearly twice the expanse of the Atlantic—its greatest breadth being 12,000 miles, and its computed area about 50,000,000 square miles. Unlike the Atlantic, it is almost entirely shut out from communication with the Arctic Ocean—the only passage of connection being that of Behring Strait, not more than 36 miles in width, with a maximum depth of 25 fathoms; but, like the Atlantic, it also opens out towards the south, and merges undefinedly into the Antarctic. It is thickly studded with islands and clusters of islands, and these physically and vitally constitute one of its most distinctive features. Its leading branches are the Sea of Kamtchatka, Sea of Okhotsk, Sea of Japan, Yellow Sea, and Chinese Sea, on the west or Asiatic side; while on the east or American

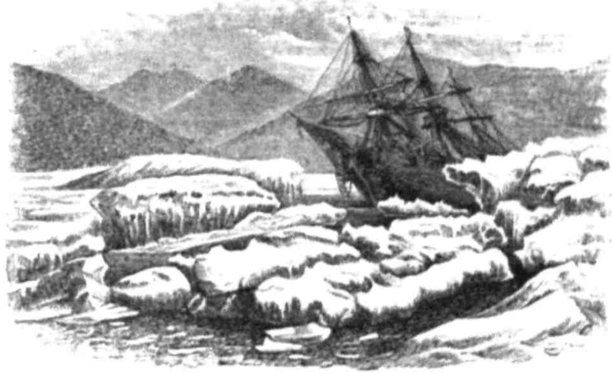
side, the Gulf of California and the small Bay of Panama are the only indentations that break the uniformity of its coasts. The most important of these minor seas are those of Japan and China, whose shores have been the seat of an early and peculiar civilisation, and whose waters have long been traversed by the ships of every other nation.

125. The Indian Ocean, stretching between Africa and Australia on the one hand, and between Asia and the Southern Ocean on the other, is upwards of 4000 miles in breadth, and is computed to have an area of about 17,000,000 square miles. If we except the Indian Archipelago, which forms its boundary rather than belongs to it, it is encumbered by few islands, and it also penetrates the land by few branches—the Red Sea, Arabian Sea, Persian Gulf, and the Bay of Bengal, being the only minor seas—and these all on its northern or Asiatic boundary. The most important of these minor branches are the Red Sea and the Bay of Bengal—the former early and intimately connected with the history of man, and the latter the leading highway of modern commerce to the varied wealth of India.

126. The Arctic and Antarctic Oceans, from their circumpolar situations, are largely blocked up by ice, and are consequently but imperfectly known to geography. The Arctic forms, as it were, a circular basin, bounded in general by the northern coasts of Europe, Asia, and America (which remarkably conform to the parallel of 72°), and having an area roughly estimated at 4,000,000 square miles. It penetrates northern Europe by the White Sea and Sea of Kara, and northern Asia by the Gulf of Obi and a few small inlets, and northwards from these shores seems interrupted by comparatively few islands. The northern shores of America, however, present so many islands and ice-locked inlets, that it has, up to the present moment (1881), been impossible to determine whether land or water continues northward and surrounds the pole, notwithstanding the repeated heroic attempts that have been made to solve the problem. As far as the Nares expedition has determined—and it reached 83° 20′ 26″ N. lat—the sea is encumbered all the year round with floebergs of considerable magnitude; hence its not inappropriate title *Palæocrystic Sea* (Gr. *palaios*, ancient; *kryos*, ice), or sea of ancient ice. At that point

the depth was 72 fathoms: with a clay bottom; a bottom temperature of 28° 8′ Fahr.; a surface temperature of 28° 5′ Fahr.; and an air temperature of 8° Fahr. on the 12th May 1876.

127. The Antarctic Ocean, on the other hand, is open on all sides to the Pacific, Atlantic, and Indian Oceans, which thus insensibly merge themselves into the great Southern Ocean. So far as navigators have ventured to



Palæocrystic Sea—after Nares.

approach the southern pole, various islands and shores have been observed which would favour the idea of a circumpolar continent; but whether land, sea, or an ice-bound archipelago occupies the immediate region of the pole, is likely long to remain an undetermined problem. Altogether the Antarctic is a cold, boisterous, and unapproachable ocean—its ice extending 10° nearer the equator than that of the Arctic—and it offers few of those inducements that have stimulated repeated research in the Northern Ocean.

128. Such are the areas occupied by the waters of the ocean—areas and subdivisions which are not only necessary to intelligible description, but which are marked in reality by different conditions and characteristics in nature. Position on the globe decides their temperature; area

depth, and configuration determine their tides and currents; and the sum of these physical conditions regulates the nature and distribution of their plants and animals. Any change, therefore, either in position, area, or configuration, would be attended by a corresponding change of conditions, and any such alteration would affect all the consequences, physical and vital, that depend on external conditions. As they exist, the North and South Atlantic, situated under different latitudes, enjoy different temperatures; while the North, by virtue of its greater irregularity of form and numerous ramifications into the land, exhibits a much more varied display of vegetable and animal life. The same also holds good of the North and South Pacific, with these important modifications, that the North Pacific, compared with the North Atlantic, is almost excluded from arctic influences; while the numerous islands of the South Pacific occasion conditions, physical and vital, peculiarly its own. The Indian Ocean, surrounded on three sides by land, and situated, for the most part, in the torrid zone, presents peculiarities unknown in other subdivisions; while the Arctic and Antarctic, receiving the minimum of solar heat, are ice-locked for the greater part of the year, and have little in common with the other sections of the ocean. As already stated, it is on these primary relations of position and configuration that the different temperatures, tides, and currents of the various oceanic subdivisions depend; and it is entirely owing to these conditions that the specific life of one sea or ocean differs from the life of all other seas and oceans. And yet it must be borne in mind that, though diversely situated and characterised, there is still the most intimate connection and interchange between their waters—the colder ever flowing towards the warmer, and the warmer towards the colder, so that in this respect they constitute in reality one great and indivisible "world of waters."

Composition, Density, Depth, Sea-bed.

129. This great ocean, in all its areas and ramifications, is characterised by a greater or less degree of *saltness*—this saltness arising from the presence of certain substances held

in chemical solution in its waters. These substances are chloride of sodium (common salt) and sulphates of magnesia and lime, together with minor and varying proportions of salts of potash and ammonia, iodides and bromides of sodium, carbonate of lime, silica, &c.—amounting in all from 3½ to 4 grains to the hundred of water. According to M. Regnault, the following is the mean of several analyses of sea-water :—

WATER,		96.470
SALINE INGREDIENTS, 3.505	Chloride of sodium,	2.700
	Chloride of magnesium,	.360
	Chloride of potassium,	.070
	Sulphate of lime,	.140
	Sulphate of magnesia,	.230
	Carbonate of lime,	.003
	Bromide of magnesium,	.002
Loss (including iodides, silica, &c.),		.025
		100.000

The preceding ingredients may vary in different seas, and according to the locality whence, and the season when, the water is taken, but only to the extent of a fractional percentage—the incessant circulation and intermingling of the ocean's waters by waves, tides, and currents, producing a uniformity, or all but uniformity, in its saline composition. It has been found, however, that the waters of the Southern Ocean are slightly salter than those of the Northern; that the greatest saltness exists along the parallels of 22° north and 17° south, or in the courses of the trade-winds, which absorb and carry off an excess of evaporation towards the equator, where it descends in freshening rainfalls; and that from these limits of maximum saltness there is a slight progressive diminution towards either pole. Though communicating freely (by currents and counter-currents) with the ocean, the majority of inland seas are less salt than the ocean, in consequence of the influx of rivers into their circumscribed areas; but some, like the Red Sea, receiving no rivers, and subjected to active evaporation, have their saltness slightly in excess. As a general rule, inland seas, receiving numerous rivers, and from their situation subjected to little evaporation, will be fresher than the ocean (*e.g.*, the Baltic and Black Sea); while a few also receiving rivers, but subjected to a more active evaporation (as

the Mediterranean), will have their saltness somewhat in excess.

130. Though the saltness of the sea is pretty uniform at great depths, still at the surface, owing to the admixture of rain, river, and iceberg water, it is not quite so salt; and this freshness will increase, of course, according to proximity to the mouths of the entering rivers. It has also been ascertained that water from the surface contains less air than that from depths, and the difference may equal one-hundredth of the volume of water; while that from greater depths is richer in carbonic acid. Another noticeable property of salt water is, that it is less sensitive, if we may so speak, to cold than fresh water—the latter freezing as is well known at 32°, while sea-water is not converted into ice till the thermometer sinks to 28¼° Fahr., and, under great pressure and stillness, even to lower temperatures. It is likewise less vaporisable than fresh water—that is, a given extent of salt-water surface gives off less vapour during the same time, and under the same conditions, than an equal extent of fresh-water surface. Such composition and properties are no doubt all-essential in the economy of nature. Shell-fish, crustacea, coral-zoophytes, and other creatures, derive the calcareous matter of their structures from the salts of the ocean; fishes breathe the aerated waters of the sheltered and undisturbed depths; and both plants and animals obtain conditions of existence which absolutely pure water would fail to supply. By its lower freezing-point a larger amount of surface is ever kept open and accessible; and by its slower evaporation a less amount of moisture is borne from its greater expanse to the comparatively smaller surface of the land.

131. It will be seen that no notice has been taken in the preceding paragraph of ingredients—sand, mud, and organic debris—that may be *mechanically suspended* in the waters of the ocean. These are purely local and accidental, depending on river-floods, tidal currents, waves, storms, and other commotions. When the commotion subsides, the waters regain their transparency; and altogether, unless along wasting shores, in tidal estuaries, and river-embouchures, there is really very little matter mechanically suspended in the waters of the ocean. On the other hand, the ingredients held in *chemical solution* are all but constant and

universal. The water that evaporates from the ocean is all but absolutely pure; it falls on the land in mist, and rain, and snow; percolates the soil and rocks; and returns again to the ocean, carrying with it the mineral substances it has dissolved from the rocky strata. The ocean is thus the great equalised repository of all that is borne from the continents; and there they would accumulate, were it not for the beautiful counterpoise that is ever kept up by the requirements of plants and animals, as well as by the intervention of new chemical arrangements among its multifarious sediments. So far as Geology can determine by a study of the marine life (shell-fish, corals, foraminifera, &c.) of former ages, the composition of the ocean seems to have been much the same as it is now; and thus, in all our reasonings, we may regard its saline contents as having long arrived at a state of equilibrium and fixity. Even if there were a slight excess at any one period, that excess would be merely temporary, as those incessant mutations of sea and land, involving the formation of new limestones, magnesian limestones, rock-salts, and the like, are ever taking up the surplus and restoring the balance.

132. *The mean specific gravity of sea-water*, as compared with absolutely pure water at 62° Fahr., is found to be 1.0275—an amount that corresponds to a percentage of 3.595 of saline ingredients. The salter, therefore, that water is, the greater its gravity; hence the fresh water of rivers, of melting icebergs, &c., will float for many miles on the surface of the sea before the two fluids be thoroughly incorporated. It is owing to this that potable water has been *skimmed* from the surface several miles from the mouths of large and rapid rivers; and it is partly for this reason of unequal densities that currents are established in different parts of the ocean—the heavier ever seeking to establish its equilibrium. On the whole, the difference in specific gravity between the great oceans is very slight: thus, in the North Pacific it is 1.0254; in the Indian Ocean, 1.0263, and in the northern part of the Red Sea, 1.0279. As already mentioned, water acquires its minimum volume, or greatest density, at a temperature of 39½°, and becomes lighter and lighter either as it rises above this temperature to its point of evaporation, or sinks below it down to its freezing-point. Again, water being slightly compressible

continents. These valleys are divided from each other by a broad ridge which runs down the centre of the ocean-basin from Iceland to the Antarctic continent. The upper surface of this central ridge reaches to within 10,000 feet of the surface, and upon it are situated the volcanic islands of the Azores, Ascension, St Helena, &c. The two grand ocean-valleys separated by this ridge descend generally to a depth of 18,000 feet, but include within them three interior depressions or "abysses" of much greater depth. The first of these hollows lies between the Bermudas and the West Indies, and has a measured depth of 23,250 feet, or more than four miles. The second occurs west of the Canaries, with a depth of 18,900 feet. The third lies midway between Brazil and the island of St Helena, and has a depth of 20,700 feet. The *Indian Ocean* has an average depth of 16,000 feet. It shows the same rapid descent along its continental margins into deep water as the Atlantic. Its interior appears to be a broad and flat depression about 18,000 feet in depth. The floor of the *Pacific Ocean*, which averages 21,000 feet in depth, is on the other hand greatly diversified. Its eastern portion is formed of an enormous ocean-valley some 18,000 feet in depth, which ranges parallel with the steeply descending edge of the American continent from Alaska to Juan Fernandez. Its central parts are apparently occupied by vast submerged platforms, which rise within 12,000 feet of the surface, and upon which are scattered the host of oceanic islands of Polynesia. The floor of its western division is formed of an alternation of submerged platforms and narrow trough-like depressions. The most southerly of its platforms supports the islands of New Zealand; the central platform is the prolongation of the partially submerged area of the East Indian Islands; the most northerly extends as far as the Sandwich Islands. The trough-like hollows and pit-like depressions between these platforms are of great depth and remarkable irregularity of form. The deepest of these hollows ranges from south-west to north-east, roughly parallel to the islands which fringe the Asiatic continent. It includes three interior abysses, which are the most profound depressions yet detected on the ocean-floor. The depression off the Ladrone Islands has a measured depth of 27,450 feet; that off the Kurile Islands one of 27,930 feet; while, according to ob-

servations made by the officers of the American navy, the depression in the immediate neighbourhood of the largest island of the Japanese group has been estimated at 30,000 feet in depth.

136. Respecting the *nature of the sea-bed*, and the materials of which it is composed, comparatively little was known, till recent years, when improved sounding-apparatus and more systematic surveys were adopted. The Mediterranean, for example, in the western portion, consists of sand and shells; in the eastern, of impalpable mud and comminuted shells; and in the Adriatic Gulf, partly of mud and partly of calcareous rock, enclosing shells, which are sometimes grouped in families. The German Ocean, according to Mr Stevenson, is traversed by extensive banks, one of which, occupying a central position, trends from the Firth of Forth in a north-easterly direction to a distance of 110 miles; others run from Denmark and Holland upwards of 105 miles to the north-west; while the greatest of all—the Dogger Bank—extends for 354 miles from north to south. The upper portion of these banks, which occupy fully one-fifth of the whole area of the German Ocean, consists of fine and coarse siliceous sands, mixed with comminuted corals and shells. Of late years most valuable additions have been made to our knowledge of the varied sedimentary deposits which cover the bottom of the great ocean-basins of the globe, especially by the recent dredgings of the Porcupine, Lightning, and Challenger, and altogether open up a new field of life and speculation to biologists. From the extended observations made during the recent Challenger expedition, it appears tolerably certain that the sediments which are at present being deposited upon the ocean-floor of the globe arrange themselves into three main groups—the coarse deposits of the shore, the soft muds or *oozes* of the intermediate depths, and the impalpable clays of the deepest abysses. The *shore-deposits* are composed of the stones, sand, and mud brought down to the sea by rivers, or washed off the sea-cliffs by the action of the waves. This material is all deposited in the neighbourhood of the present coast-lines. The stonier and heavier matter is distributed along the edge of the coast-line itself, the sands are swept out into deeper water, while the very finest muds are carried some distance out to sea. It is very

doubtful, however, if any notable quantity of these land-derived sediments is carried as much as 200 miles from shore. In all probability the shore-deposits form a mere coast-fringe to our mainland areas, of a breadth varying from 50 to 150 miles. Outside this fringe of shore-deposits, and occupying those enormous areas of the ocean-floor which vary from one to two and a half miles in depth, are found the *Deep-sea Oozes*. These consist of fine muds, generally white in colour, and when dried resembling powdered chalk. The most widely distributed of these pale muds is the well-known Globigerina ooze, which covers vast spaces in the Atlantic, Pacific, and Indian Oceans. It contains from 40 to 80 per cent of carbonate of lime, and is almost entirely made up of the microscopic shells of a single genus (Globigerina) of the group of the Foraminifera. These creatures live near the surface of the ocean, their shells (which are so minute that 15,000 occupy the space of a square inch) sinking to the bottom after the death of the animal. In the Antarctic Ocean, south of the Cape of Good Hope, the place of the Globigerina ooze of the Atlantic is taken by a siliceous ooze (*Diatomaceous ooze*), formed of the remains of similarly minute microscopic plants (Diatoms). In the deepest areas of the central Pacific another siliceous ooze is met with (*Radiolarian ooze*), formed of the shells of microscopic animals closely allied to the Foraminifera, but having siliceous shells, and existing at all depths in the ocean. In descending to depths exceeding two and a half miles, the calcareous shells of the Globigerina ooze are found gradually to grow more and more decayed, and finally to disappear altogether, and the floor of the most profound depths of the ocean is covered by the very distinct *Abyssal Clays*. These are of a deep purple, chocolate, or dull brownish-grey colour, and are generally wholly destitute of calcareous matter. The actual derivation of the material of these abyssal clays is not yet satisfactorily determined; but it has been suggested that it is in great part identical in origin with the Globigerina ooze already described, being similarly derived from the remains of the calcareous Foraminifera living upon the surface of the ocean. The lime forming the main mass of these shells is supposed to be dissolved by the excess of carbonic acid known to occur in the sea-water at these extreme depths, and the red clay is supposed to be

made up of the non-calcareous residue. Great force is given to this opinion by the fact that when the Globigerina ooze is treated with acids, the residue is almost identical with this coloured clay. It is believed, however, by Mr Murray of the Challenger, that the abyssal clay is derived also in great part from the disintegration of pumice, which is found floating in small quantities upon the surface of the ocean in all regions, and fragments of which occur in more or less abundance in the red clay itself. The inconceivable slowness of the gradual accumulation of this deposit not only follows of necessity if this be actually its mode of origin, but it seems to be placed wholly beyond question by the fact that the half-fossilised bones and teeth of extinct fishes have been found to lie in many areas almost unburied upon its surface, preserved from complete dissolution by a coating of the black oxide of manganese, possibly derived from the volcanic products already referred to; while the red clay itself contains an abundance of minute specks of iron, like those occasionally collected off the surface of long-frozen snow, and which are supposed to be the dust of shooting stars.

Temperature, Colour, Luminosity.

137. Respecting the *temperature of the ocean*, all our trustworthy information is of recent date, and much remains to be discovered as regards its various areas and its successive depths. We know, however, that it is more equable than that of the land, and that, though the superficial portions are colder in summer than the surrounding atmosphere of any contiguous terrestrial district, they are in winter always several degrees higher—thus exercising the function of a great storehouse of heat for modifying and equalising the climates of the adjacent land. This arises from the high *specific heat* of the waters of the ocean, as contrasted with that of the rocky substances of which the land surface is composed. It is calculated that four times as much heat is necessary to raise water to the same temperature as the land. As a greater amount of heat is thus required to warm the water up to the same point as the land, so a greater amount must be given off before it can be reduced to the same temperature. The surface temperature is necessarily

highest along the equator—or rather along a belt, varying from 2° to 8°, on either side of the equator—and thence gradually diminishes as we approach either pole. Along this equatorial zone, temperatures have been found ranging from 78° to 85°—higher exceptional temperatures (87° and 88°) having occasionally been taken in parts of the Indian Ocean and the Gulf of Mexico. Though varying in *surface temperature* according to latitude—from 80° at the equator to perpetual ice towards either pole—it has yet been found that at very great depths the ocean preserves a pretty uniform but not altogether equable temperature.

138. The first to attempt a connected account of the distribution of ocean temperature was Sir James Ross, who, from experiments conducted by himself in his Antarctic voyages, drew the following conclusions: The circle of the mean temperature of the ocean in the southern hemisphere lies between the 56th and 59th parallels of latitude; along which belt the uniform temperature of 39½° was thought to prevail at all depths, from the surface downwards. To the south of this line, owing to the absence of solar heat, the surface depths are colder, and the mean of 39½° is not reached in the 70th parallel till we descend to the depth of 4500 feet, beneath which to the greatest depths the temperature is uniformly at 39½°, while the surface temperature is only 30°. To the north of the line of mean temperature, in consequence of the absorption of the sun's heat, the surface depths are warmer; and in the 45th parallel the mean of 39½° is not reached till we descend 3600 feet; while at the equator we have to descend 7200 feet before the same mean is obtained, and then at all depths below this it maintains the unvarying mean temperature of 39½°, though the surface is at 80°. Presuming that a similar order prevails in the northern hemisphere, we have thus three great regions of oceanic temperature — an equatorial and two polar, the former characterised by warm water at the surface, and the latter by cold.

139. This generalisation of Sir James Ross has recently been wholly disproved by the experiments of Drs Carpenter and Wyville Thomson on board the Porcupine and Lightning during the summers of 1868-69-70, when surveying (dredging and sounding) in the North Atlantic. Instead of finding at great depths a uniform temperature of 39½°,

they ascertained that in some areas the thermometer fell to 30° and 29° (or that of ice-cold water), while in other areas it rose to 44° and 46°; thus showing that in the region within and beyond the Faroe Islands at least, there were colder and warmer reaches of sea-water. These facts were subsequently corroborated by the more protracted experiments of the Challenger expedition. At a depth of about 500 fathoms, over the greater part of the regions surveyed, the temperature of the water of the ocean-basins was ascertained to be tolerably uniform, varying from 40° to 45° Fahr. Below this line the temperature sinks very slowly and gradually, until in the deepest areas it descends even below the freezing-point of fresh water (32°). In other words, the great ocean-basins are filled to four-fifths of their total capacity with water of a temperature only a few degrees above the freezing-point. This cold water is apparently derived from the polar oceans, almost entirely from the Antarctic, and creeps gradually over the ocean-floor in the direction of the equator, where the line of 40° Fahr. approaches within 300 fathoms of the surface, and the bottom temperature is occasionally as low as 32.7°. The temperature of the ocean-waters, above the line of 500 fathoms, varies with the locality, and seems to be dependent upon conditions of latitude, prevalent winds, currents, and the like, and varies from an extreme of 83½° under the equator, to below the freezing-point in high latitudes. This generalisation, however, must be regarded as merely approximative. The depth of the superficial and heated stratum of water is much greater in the North than in the South Atlantic; the datum line of 40° being reached at a depth of a mile or more in the latter, while in the former it occurs at a depth of about half a mile. This exceptionally high temperature of the North Atlantic is possibly a result of the influx of the super-heated waters of the current of the Gulf Stream. There are also local variations of very doubtful origin, as in the Faroe Channel, where bottom temperatures, differing as widely as 32° and 46° Fahr., occur side by side in the same area, and at about the same depth. Again, in certain local depressions of the ocean-floor the temperature of the sea is found to decrease in the normal manner to a certain depth, beyond which it remains without further change to the bottom. This has been explained by the

theory that the abyssal waters in these depressions are cut off from the general circulation, the margin of the basin they occupy being elevated above the lowest horizon of ocean temperature; the constant temperature of the waters of their lower depths being that of the deepest stratum of polar water which is able to make its way over the margin. Thus in the partly enclosed China, Sulu, and other seas to the east of Asia, the minimum temperature is met with at 500 or 600 fathoms, and remains constant to the bottom; this minimum temperature apparently affording an index of the height of the rocky barrier separating these basins from the ocean depths. We have a striking example of the same phenomenon in the N. Atlantic. The deep waters filling its two great depressions have a uniform temperature of 35° below a depth of 2000 fathoms—that being the height of the ridge preventing the influx of the much colder Antarctic waters from the south. The depression off the coast of Brazil, on the other hand, being open to the southward, has its bottom water reduced to a temperature of 33° Fahr.

140. Such are the facts, so far as ascertained, respecting the general temperature of the ocean; but inland seas and currents may be colder or warmer according to the position they occupy and the direction in which they proceed. The surface temperature of the Gulf of Mexico, for example, is several degrees warmer than the main Atlantic under the same latitude; the waters of the Gulf Stream are also several degrees higher in a large portion of its course than those through which it flows; while the Arctic Current, on the other hand, is considerably colder. Of inland seas, the Mediterranean is the only one whose temperature has hitherto been carefully studied. In this enclosed area the limit of invariable temperature is met with at a depth of about 100 fathoms. At this horizon a temperature of 54° or 55° is met with and remains constant to the bottom, even where the waters exceed 12,000 feet in depth. Above this 100-fathom line there is a rapid rise from 54° to a maximum temperature of 78° upon the surface. This curious uniformity of temperature of the waters at great depths in this sea is easily explained by the fact that its interior hollows are cut off from the general ocean circulation, the shallowness of the Strait of Gibraltar preventing the entry of

the cold polar water into the basin. The temperature of the waters in its depressions appears to be identical with that characteristic of the crust of the earth in the neighbouring countries. Contrasting the temperature of *inland seas* with that of the *outer ocean*, "it may be regarded as a general rule," says a high authority, "that all inland seas at great depth, represent nearly the mean temperature of the earth in the latitude where they are situated; whilst in the ocean, the low temperature of the bottom in every latitude is produced by the cold currents setting in eternally from the polar regions."

141. Besides the preceding conditions of saltness, density, depth, and temperature, there are also those of *colour* and *luminosity*, usually adverted to by navigators and geographers. In small quantities, water is generally regarded as colourless, but that of the ocean assumes different hues, and this altogether independent of the colours of the sky which may be mirrored on its surface. Thus, in the open ocean, shallow water is indicated by a *green tint* of different degrees, while profound depths are characterised by an *indigo blue*. Whether this arises from the greater density of the mass, from some peculiarity of its saline constitution, or, as suggested by Professor Tyndall, from infinitesimally small particles held in suspension, is not yet satisfactorily known; but the fact remains, and "sea-green waves" and "dark-blue oceans" are something more than mere poetic fancies. Of course, in some localities there may be accidental or even permanent discolorations, arising from the entrance of river-water, from peculiarity of bottom, or from the presence of countless myriads of vegetable and animal organisms; hence the application of such terms as Red, Black, White, Yellow, Green, and Vermilion to certain seas and areas of the ocean. In general, however, the ocean-water is clear and limpid, and, under favourable circumstances, objects are reported to have been seen at a depth of 300 feet, or about half the distance to which the sun's light is supposed to penetrate into the abyss of waters. Actual experiment, however, in the Mediterranean, shows that a white disc eleven feet in diameter becomes invisible at a depth between 150 and 160 feet.

142. The phenomenon of *luminosity or phosphorescence* is less general, perhaps, and seems to depend in a great de-

gree on locality, season of the year, and state of the weather—being most frequent, brilliant, and continuous in tropical latitudes. Luminous animalcules, and creatures of various kinds, together with decaying animal matter, appear to be the proximate cause of the phenomenon, which becomes most apparent in still, dark nights, and where the surface of the water is disturbed by the stroke of an oar, or the friction of a passing keel.

RECAPITULATION.

143. In the preceding chapter attention has been directed to the main natural divisions of the Ocean; to the composition, density, depth, and temperature of their waters; and to the waves, tides, and currents by which they are respectively traversed. The divisions of the ocean into Pacific, Atlantic, Indian, Arctic, and Antarctic areas, are sufficient for the ordinary purposes of description; and the nomenclature of their various ramifications after some discoverer, position, adjacent country, colour, or other peculiarity, has been long established in general geography. Their further subdivision into *zones*, *belts*, *regions*, and the like, comes under the consideration of Climatology rather than of Hydrography; and the technicalities (bays, gulfs, straits, creeks, &c.) by which their minor sections are distinguished, have been already noticed in par. 50. Their dimensions are matters merely of measurement and calculation; their composition, depth, temperature, and the like, are subjects for experiment and observation. Occupying different positions on the earth's surface, and having different configurations, the oceans and seas, properly so called, are necessarily characterised by different physical and vital conditions. The Pacific, almost shut out from the influences of the Arctic Ocean, is in a different condition from the Atlantic, which communicates freely with the north; while the Indian Ocean, encircled on three sides by land, and lying largely in the torrid zone, presents external con-

ditions differing widely from either. All three open broadly to the great Southern Ocean, from which they receive the primary impulse of their tides and currents; but while the Indian and Atlantic are deep and free, the Pacific is largely obstructed by reefs and islands. It should also be borne in mind that the main oceans, like the great continents, lie meridionally, or at right angles to the equator, and are thus prevented, by the intervention of the land, from receiving in their winds, tides, and currents, the normal effect of the earth's daily rotation.

144. Though differing slightly in different areas, the composition of sea-water is, on the whole, very equable, and 3½ per cent of saline ingredients may be set down as the general average. Along the courses of the trade-winds, in circumscribed seas, and other similar areas subjected to active evaporation, this percentage may be slightly increased; while in others it may be correspondingly decreased by periodical rainfalls, by the melting of polar ice, or by the influx of large and rapid rivers. The average density of sea-water, as compared with pure water at 62° Fahr., is 1.0275; and this density, corresponding as it does with an average saltness of 3½ per cent, will decrease where the water is fresher, and increase where it becomes salter than the general average. This saltness and density renders the ocean less vaporisable than fresh water, and also keeps it longer from freezing—the freezing-point of fresh water being 32° Fahr., while that of sea-water is 28½°. The superficial waters of the ocean are characterised by their incorporating an abundance of atmospheric air or oxygen; while the deeper waters, as a rule, contain an excess of carbonic acid. This composition is in accordance with the demands of its plant and animal life; and though the rivers are incessantly carrying in fresh accessions of saline matter, the equilibrium is ever maintained by the chemical interchanges that take place.

145. The average depth of the ocean is estimated at 3

miles, and reliable soundings have been taken at nearly 5¼ miles. So far as we know, the ocean-bed has its deeps and shoals, its troughs and ridges, like the surface of the dry land. In fact it is, in all probability, nothing but the submerged surface of former lands—the crust-elevations forming the dry lands, and the crust-depressions filled by the waters of the ocean, gradually but irregularly interchanging their positions in the progress of long geological ages. The temperature of the superficial layers of the waters of the ocean depends upon the latitude, the season of the year, and generally upon the local amount of heat received from the sun; declining irregularly from the torrid heat of 78° or 88° at the equator, to the perpetual frost of the polar regions. In the torrid and temperate zones the heat of the water declines rapidly to a depth of about 500 fathoms, where there is found to be a uniform temperature of about 45°. Below this invariable horizon the temperature sinks very slowly to the bottom. Where the depth is greater than 2000 fathoms, the temperature of the bottom layers is slightly above the freezing-point of fresh water (32° Fahr.); in the most profound depths it occasionally falls below it. It must be borne in mind, however, that this normal temperature is greatly interfered with by surface-drifts and deep-sea currents—some areas being colder and some warmer, according to the direction from which or to which the current flows.

IX.

THE WATER—ITS OCEAN AND OCEAN-CURRENTS.

Waves—their Magnitude, Velocity, and Impact.

146. LIKE other fluids whose particles are free to yield to every impulse, the waters of the ocean are subject to several movements, the more important of which are waves, tides, and currents. Waves are produced by winds, and occasionally by earthquake commotion; tides by the attraction of the moon and sun; and currents chiefly by that incessant tendency which waters of different densities and temperatures have to assume a state of equilibrium. And first of WAVES, whose main characteristics are magnitude, velocity, and force of impact. Waves occur in every part of the ocean, and wherever the wind blows,—the aerial current drifting by its friction and impact the surface waters along with it, and producing undulations, which increase, according to the power of the propelling force, from the gentlest ripple to billows 30 or 40 feet in height. In deep and open seas a continuous wind produces merely an undulation or up-and-down movement of the surface waters; and this commotion, even in the case of a wave a quarter of a mile in breadth and 40 feet high, is not sensibly felt at a depth of 220 fathoms. But in obstructed and shallow seas, the lower part of the advancing undulation is retarded by frictional contact with the bottom — the upper portion advances with headlong motion, and ultimately breaks with forcible impact on the opposing shore, which is worn and abraded by the backward and forward motion of the surf.

147. Such is the beginning, course, and termination of ordinary waves: at first a mere ripple; as the gale increases, a long roll and swell in the deep sea; and ultimately a cresting and dash of breakers on the shelving shore. Occasionally, however, the wind shifts, and sets in waves from opposite directions, and these crossing and commingling produce a violent commotion, even far out at sea, and in the deeper waters. The aspects and characters of waves are known to sailors by many different names; the ruffle or ripple under a rising breeze being spoken of as a *catspaw*, the long undulation as a *swell* or *billow*, the shorter undulations as they approach the shore as *rollers* and *breakers*, and the broken water along the shore as *surf*. The high heavy waves that occasionally set in when there is no wind (having been produced by storms far out at sea) are said to form a *ground swell;* the commotion produced by cross-waves forms a *chopping sea*, and in a less degree a *jabble* or *cross-lipper*, and the sudden drift, or rather lift, of the surface waters before a violent hurricane is known as *spoon-drift;* but these and similar terms belong more to nautical technicality than to the generalities of Physical Geography.

148. Generally speaking, the magnitude of *wind-waves* has been greatly exaggerated, partly from the difficulty of making correct observations, and partly from the impression of dread produced on the mind of the observer. The greatest waves known are said to be those off the Cape of Good Hope, where, under the influence of a north-west gale, they have been found to exceed 40 feet in height. Off Cape Horn they have been measured at 32 feet from trough to crest. In the North Atlantic, waves from 20 to 25 feet are by no means uncommon, while waves of even 43 feet in height have been measured in stormy weather. In the Bay of Biscay, under violent gales they have been known to attain a height of 36 feet. In our own seas, however, they rarely exceed 8 or 10 feet; and all accounts of their running "mountains high" must be received as mere poetical exaggerations. In the case of *earthquake-waves* the conditions are altogether different; and as the whole mass of water is then thrown into commotion by sudden and abrupt risings, fallings, and whirlings, waves, or rather walls of water, 60 or 80 feet high, may be thrown with tremendous impetus upon the land. In the Lisbon earthquake of 1755, the destruc-

tive wave that rolled in upon the coast of Portugal was estimated at 60 feet ; and in the Simoda (Japan) earthquake of 1854, three huge waves, at intervals of a few minutes, rushed into the bay, destroying the native craft, and completely submerging the town of Simoda.

149. The velocity of waves depends primarily, of course, upon the power and continuance of the wind, but is greatly modified by, and bears an ascertainable relation to, their magnitude, and the depth of the water over which they travel. Thus it has been calculated by Professor Airy that a wave 100 feet in breadth and in water 100 feet deep travels at the rate of about 15 miles per hour ; one 1000 feet broad and in water 1000 feet deep, at the rate of 48 miles ; whereas another, 10,000 feet in breadth, and in water 10,000 feet deep, will sweep forward with a velocity of not less than 154 miles per hour. The force with which a wave strikes against any opposing barrier depends, in like manner, upon its bulk and velocity, and in the case of huge waves this impact is enormous. From experiments made at lighthouses and breakwaters, their effective pressure during severe storms has been estimated as high as 6000 lb. per square foot : and one has only to observe the breaches occasionally made in sea-walls, and the distance to which blocks of stone, several tons in weight, have been hurled forward, to be convinced of their great propulsive power. Of course the force with which a wave simply *strikes* is not to be altogether estimated by its propulsive power, for substances submerged in water lose a certain portion of their weight, which greatly facilitates their displacement and transport.

Tides—their Origin, Characteristics, and Influence.

× 150. The next, and perhaps the most important and persistent of oceanic movements, is that of the TIDES—a term applied to the periodic rising and falling of the waters, occasioned chiefly by the attraction of the moon, but partly also by that of the sun. In obedience to the universal law that × "every particle in nature attracts every other particle with a force inversely as the square of the distance," the earth is attracted by the sun and moon, but more by the latter, in proportion to its greater proximity. Land and water alike experience this attraction, but the particles of the latter

being free to move among themselves, the mass of the ocean is drawn out beyond its normal circumference towards the attracting bodies. Had the earth been immovable as regards the sun and moon, this bulging-out of the waters would have been stationary; but as she turns on her axis, meridian after meridian is brought directly opposite to the attracting force, and thus the rising of the waters becomes a great *tidal wave* or *flow* that travels round the globe. The moon, we have said, exercises the greater attraction; but when the sun and moon are in conjunction, or in opposition (that is, at new and full moon), the sum of the two attractions will cause the greatest possible rise, known as *spring-tides;* and when the moon is in her quadratures (that is, at her first and last quarters), the sun's attraction, acting in a different direction, will diminish the lunar tide, and then we will have the least rise, or *neap-tides*.

151. The following diagram may assist the comprehension of these phenomena:—

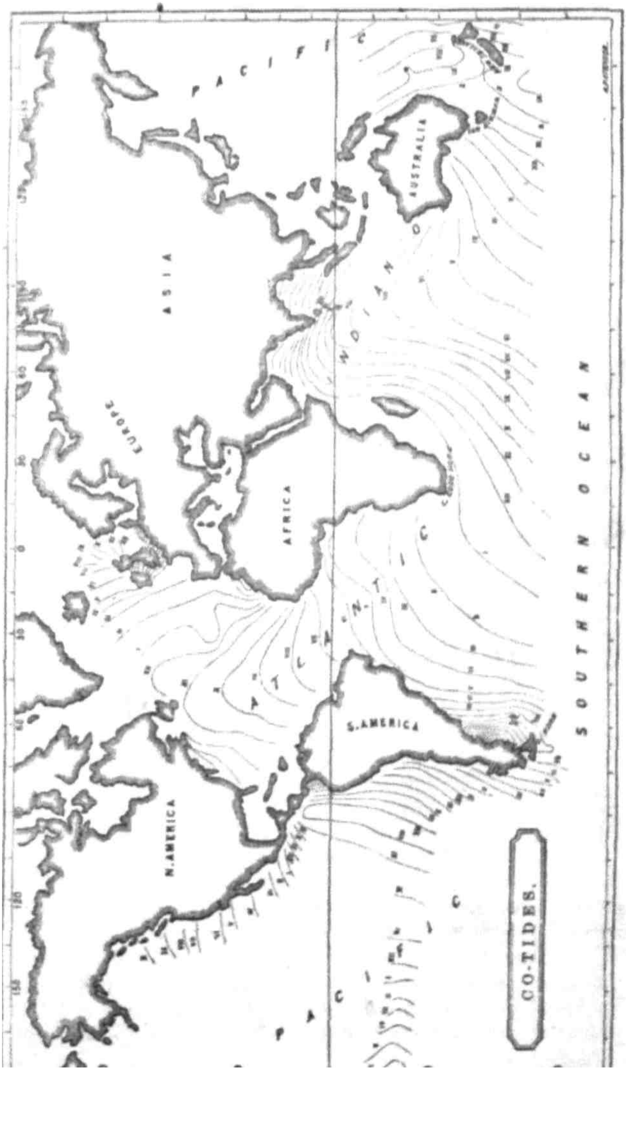
Here *t* being the nearest point of the earth's surface to the moon, the waters at that part are most attracted towards that luminary, and of course rise highest; while on the opposite side at *t'* the earth is drawn, as it were, away from them, and they stand out nearly at the same height as those at *t*. Thus two great waves of water are formed on opposite sides of the globe, having their crests at *t t'*, and their intervening hollows midway between these points, as at *e e'*. As the earth revolves, these two tide-waves with their separating depressions follow after each other in regular succession; and each point on its surface will necessarily have two high-waters and two low-waters per day. In other words, the sea *flows* or rises as often as the moon in her apparent circuit passes the meridian, both of the arc above and the arc below the horizon, and *ebbs* or falls as often as she passes the horizon, east and west. The solar day, however, being only 24 hours, and the lunar (owing to the moon's monthly course round the earth) being 24 hours, 54 minutes, it

requires rather more than a rotation of the earth to bring the same meridian to the same position, relatively to the moon, as it had the preceding day. In other words, it requires about 24 hours 50 minutes to bring the moon round to its vertical position over any given place, and thus the tides of one day are always about an hour later than they were on the preceding day. Again, had the moon been the sole attracting body, the tides would have risen always to the same height; but the sun, exerting a simultaneous attraction either along with or against that of the moon, creates an alternate maximum and minimum of flow. Thus when the sun is at S and S′ his attraction is combined with that of the moon, and a higher tide is the result. When at S the darkened side of the moon will necessarily be towards the earth, and it is new moon; and when at S′ the illuminated face of the moon will be towards the earth, and it is full moon; so that the higher or *spring tides* take place alternately at new and full moon. On the other hand, when the moon is 90° from the sun's place (that is, when she is in her first and last quarters, or half-moon), his attraction, being exerted at right angles, counteracts that of the moon, and the result is the lower or *neap tides.* The greatest tides occur, of course, when the luminaries are nearest and pass most vertically to the place of observation; and as each tide has only about six hours to *flow* and about six hours to *ebb*, the highest must necessarily be the *swiftest* and the lowest the *slowest.*

152. Such, in general terms, is the theory of the tides; and had the surface of the globe been entirely covered with water, the tidal wave would have been regular and continuous from meridian to meridian, and, as a consequence, highest in the region of the equator, and gradually falling away towards either pole. But the continuity of the ocean being interrupted by land, and this land lying in a great measure meridionally, as well as being irregular in outline, and consisting in many parts of islands, the course of the tidal flow is obstructed and deflected into various courses. Under the present arrangement of sea and land, these courses are, however, sufficiently persistent; and thus their directions, times, velocities, and heights, can be determined with accuracy for the purposes of navigation. The Southern Ocean, encircling the globe, and being comparatively

uninterrupted by land, may be regarded as the area in which the tidal wave receives its great primary impulse. It is thence carried forward, deflecting itself northward into the Indian, Atlantic, and Pacific Oceans, where, uniting with the minor tide-waves generated in these expanses, it flows, rises, and subdivides, according to the outline of the coasts, the depth of water, and the obstruction of islands. Notwithstanding the complications arising from these causes, there is still great regularity in the bi-diurnal flow and ebb of the tides; and by noting the times at which the same high-water reaches different parts of the coast, a series of lines connecting these points may be laid down so as to indicate the course of the tidal wave with great precision. Such a series of lines are termed *co-tidal* lines, or lines of simultaneous tide, and mark the progress of the summit of high-water from its origin in the Southern Ocean to its remotest ramifications in northern waters. We say northern waters; for though the primary and normal direction of the tidal wave is from east to west, in obedience to the apparent course of the sun and moon, yet, on entering the troughs of the Indian and Atlantic Oceans, it is compelled to assume a northerly course in accordance with the configuration of these seas. Thus, the new or full moon high-water that passes Tasmania every morning at twelve o'clock, takes twelve hours to reach Ceylon, and thirteen to reach the Cape of Good Hope; in another twelve hours it has passed up the Atlantic and arrived at Newfoundland; at the end of the third twelve it has rounded the north of Scotland, and is opposite to Aberdeen; at the fourth twelve, or at midnight of the second day, it is opposite the mouth of the Thames; and it is "not till the morning of the third day that this wave fills the channel of the Thames, and wafts the merchandise of the world to the quays of the port of London." (See Map of *Co-tides*, page 139.)

153. The tides, we have said, may be regarded as taking their rise in the uninterrupted expanse of the Southern Ocean. As the wave proceeds westward, it is deflected northward broadly into the Indian Ocean, rapidly and deeply into the larger channel of the Atlantic, and slowly and feebly into the Pacific, where its course is obstructed by numerous islands and coral-reefs. The *velocity of the tidal wave* depends primarily on the conformation and


ASIA
EUROPE
AFRICA
AUSTRALIA
N. AMERICA
S. AMERICA
SOUTHERN OCEAN
CO-TIDES.

depth of the ocean—proceeding with the greatest rapidity where the ocean is freest and deepest. As the co-tidal lines are laid down at hourly distances, they afford a pretty correct estimate of the tidal velocity—the wider the lines (that is, the greater the distance travelled over in one hour) the greater the speed, and the closer the lines the slower the rate of progress. In the free depths of the Southern Ocean, this velocity may equal 1000 miles per hour, while in restricted seas like the North Sea the rate is scarcely a twentieth of that amount. As the tidal wave agrees with the wind-wave in being a mere undulation and not a wave of translation, so where the natural movement of its lower parts is retarded by friction, it similarly loses its natural character and assumes that of an actual current. In the open expanse of the Southern Ocean, as well as over a large portion of the Pacific, the tidal wave rarely exceeds five or six feet, and in the Indian and Atlantic Oceans, perhaps eight or ten; but in bays and gulfs opening broadly to its course, and narrowing towards their interior recesses (such as the Bay of Bengal, our own Bristol Channel, and the American Bay of Fundy), it may rise to 20, 30, or, under favourable circumstances, even to 50 or 60 feet in height. And where such seas terminate in river-estuaries, the wave, still converging, forms a high head or wall of water, termed a *Bore* (provincially an *Ægre*), which ascends the river with sudden and destructive impetuosity. Such are the tidal bores of the Tsientang, which are said to extend across the river 30 feet high, and ascend with a velocity of 25 miles per hour; of the Hooghly, 20 and 25 feet high; of the Sakerang, in Borneo, 10 and 12 feet; of the Garonne, 10 and 12 feet; the Severn, 9 feet; the *ægre* of the Ouse from 2 to 3 feet; the Amazon, 12 and 13 feet; and other rivers, whose gradually narrowing estuaries are exposed to the concentrated incidence of the tidal wave. On the other hand, inland seas and gulfs, whose openings are narrow, and lie transversely to the course of the tidal wave (as the Mediterranean and Baltic), experience little or no rise, and are next to tideless. Not only is the primary wave that sweeps up the Atlantic excluded from such seas, but their own areas are too limited to admit of the formation of any perceptible tide-wave of their own; and thus, for all practical purposes, strictly inland seas and lakes may be considered as tideless.

154. The mechanical effects of the wind-waves are felt chiefly along the shore-line in their battering, wearing, and abrading action; the tide-waves, on the other hand, in shallow seas and narrow gulfs, act more like currents, which, in their ebb and flow, are ever transferring, arranging, and re-assorting the sediments below. The wind-wave may be stilled, and the surface of the ocean be as smooth as a mirror; or the wave from one direction may counteract that from another: but the ebb and flow of the tidal wave is regular and incessant, and in its direction, time, height, velocity, and local power, will continue the same while sea and land remain undisturbed in their present relations.

Currents—Constant, Periodical, and Variable.

155. We now proceed to what are termed the CURRENTS of the ocean—movements which, like great rivers, are ever transferring the waters from one region to another. They form, in fact, the circulatory system by which the ocean is maintained in a state of equilibrium. As to their actual causes, scientific men are not fully agreed. By Dr Carpenter and others it is believed that they depend primarily upon the unequal temperatures and densities of different zones of the ocean, and the unequal evaporation sustained by these zones, which modifies the directions imparted by the primary causes. Wherever we have waters of different temperatures, or, what is the same thing, of different densities, there the lighter will ascend and the heavier descend; and wherever a deficiency takes place through evaporation, there the waters will flow in from the adjacent parts to make up the deficiency. But differences of density may also arise from different degrees of saltness, and wherever the salter water subsides and flows off as an under-current to some fresher region, there at the same time will the fresher and lighter flow in from above to restore the equilibrium. By Dr Croll and others it is contended that the grander currents owe their origin solely to the action of the prevailing winds, which force the surface waters before them in certain regions, and that the movement thus established necessarily draws the remaining waters into the general circulation. But whichever theory we accept, if we bear

in mind that the continuity of the ocean is interrupted by continents and islands, reefs and shoals, and further disturbed by local winds and periodical variations of temperature, it will readily be seen why its currents should assume different characters and courses. In fact, the currents and counter-currents of the ocean are extremely complicated; and though the courses of some of the main streams are intelligible enough, there remains very much to be done in this department of Hydrography.

156. It is usual to arrange the ascertained currents into *constant*, *periodical*, and *variable*,—the constant being those we would refer to the combined influences of unequal temperatures and densities in the waters of the ocean, the rotation of the earth, and the trade-winds; the periodical being those originated by the tides, the monsoons, and the sea and land breezes in tropical countries; and the variable, such as may be produced by local peculiarities in the tides and winds, the melting of ice in polar regions, and other similar causes. It is also customary to speak of *drift-currents* and *deep-sea currents*, — the former being beyond question due to the local agency of the wind, and only affecting the waters to a trifling depth—the latter arising from the great primary causes of ocean circulation above alluded to, and extending their influence hundreds of fathoms beneath the surface. In like manner, it may be useful to note the distinction between a *marine* or upper current, and a *submarine* or under current; between a *current* flowing one way and a *counter-current* coming from an opposite direction; and between the mode of naming winds and water-currents,—the former being named after the direction *from* which they blow, as a "west wind," that is, one blowing from the west—and the latter after the direction *to* which they are flowing, as an "easterly current," that is, one flowing towards the east.

157. The constant and deep-sea currents being the most important, it is to these and these alone that we would first direct attention. As already mentioned, the heat of the torrid zone diminishes the specific gravity of the equatorial waters, and occasions a greater evaporation there than in any other region; and, as a consequence, the waters of the polar regions set in, chiefly as under-currents, towards the equator to restore the equilibrium; while, at the same time, an

abyssal body of ice-cold water of enormous depth creeps along the bottom of the ocean both from the north and the south towards the equatorial regions. Here the united waters growing warmer and warmer, gradually rise to the surface, where they come under the influence of the trade-winds. These force them swiftly onwards in a westerly direction in the form of the well-known equatorial currents; in which a portion is evaporated, while the remainder overflow as warmer and lighter surface-currents northwards and southwards to either pole, again to become colder, and again to find their way to the equator in incessant circulation. From these four primary flows — the two from the poles towards the equator, and the two from the equator towards the poles—arises the great circulatory system of the ocean, which is modified and broken up into a number of minor currents by configuration of coast, form of bottom, unequal reception of heat by different areas, the influx of rivers, and other kindred causes. These various currents, having different directions, volumes, velocities, and temperatures, will be better understood, perhaps, by being arranged under the three great oceans—Atlantic, Indian, and Pacific—in which they respectively occur.

158. The principal and better known currents of the Atlantic are the Equatorial, the Guiana, the Brazil, the Gulf Stream, the Guinea, and the Arctic. Besides these, there are some minor drifts and branches, the courses of which will be better understood by reference to the map (page 145) than by any amount of description. The *Equatorial*, as the name implies, manifests itself chiefly in the region of the equator, and flows across the ocean from the African towards the American continent. When more than half-way across it shows a tendency to bifurcate into a north-west branch and a south-west branch, and this tendency increases till within 300 or 400 miles of Cape St Roque, when it fairly divides — sending one main stream northwards by the coasts of Guiana into the Caribbean Sea; and another, somewhat feebler, southward along the shores of Brazil. The length of the Equatorial Current, from the coasts of Africa to the Caribbean Sea, is about 4000 miles; its breadth at its commencement, 160—and where it divides, 450 miles; its velocity is from 20 to 60 miles a-day; and its average temperature about 75° Fahr., or from 4° to 6° under

that of the ocean through which it flows. Its southern or *Brazil* branch flows at a distance of about 250 miles from the coast (the intermediate space being occupied by variable currents), and at the rate of 25 miles per day; a rate, however, that is sensibly diminished by the cross stream from the Plata, and which gradually declines till the current ultimately dies away near the Strait of Magellan. The north-west branch of the Equatorial, spreading out as it proceeds and gradually diminishing in speed, ultimately merges into the drift of the north-east trade-winds; while the *Guiana* section proceeds unimpeded to make the circuit of the Caribbean Sea and the Gulf of Mexico.

159. As it makes the circuit of the Caribbean Sea and the Gulf of Mexico, this western branch of the Equatorial Current acquires more heat, a greater degree of saltness, and that intense blue colour so characteristic of briny waters. With these new acquisitions it leaves the Mexican Gulf, and, pressing through the narrow channel of Florida, which is only about 32 miles in width, becomes the celebrated *Gulf Stream*—of all the Atlantic currents the most wonderful in its character and the most important in its results. Doubling the Cape of Florida, this Gulf Stream (that is, stream from the Gulf of Mexico) flows north-east in a line almost parallel to the American coast; touches the southern borders of the banks of Newfoundland; and thence, with increasing width and diffusion, proceeds across the Atlantic, till, in the region of the Azores, it spreads out into two great branches — one curving southwards towards the equator, and the other flowing northwards, impinging in its course against the western coasts of Europe, and ultimately losing itself in the waters of the Arctic Ocean. The length of this great ocean-river from its commencement to the Azores is 3000 miles, and its greatest breadth about 120 miles. When it leaves the Strait of Florida its velocity is about 4 miles an hour; off Cape Hatteras, in North Carolina, it is reduced to 3 miles; on the Newfoundland banks it is further reduced to 1½ mile; and this gradual abatement of force continues with its diffusion across the Atlantic. A similar decrease takes place in its temperature, the maximum of which in the Strait of Florida is 86°, or 9° above that of the ocean in the same latitude. Off Newfoundland, in winter, it is said to be from 25° to 30° above

CURRENTS.

the water through which it flows; in mid-ocean from 8° to 10°: nor is the heat wholly lost when it impinges against the shores of western Europe. The Gulf Stream is thus, in reality, a great thermal ocean-river, incessantly flowing from warmer to colder regions, diffusing warmth and moisture along its course, and tempering the climates of countries that lie within its influence. Compressed, as it were, at its commencement between two areas of colder water, its deep-blue warm current rises in convexity above the surrounding ocean; but as it proceeds it cools, becomes diffused, assumes the ordinary level, and partakes of the greener hue of northern waters. It sets a limit to the southward flow and chilling influences of the Arctic iceberg, that melts away in its warm stream—and it becomes at the same time the great natural barrier between the life of the Northern and Southern Atlantic.

160. The Equatorial Current, flowing westward from Africa to the Gulf of Mexico, and the Gulf Stream, flowing from that gulf eastward to the Azores and thence curving southwards, produce a great whirl, as it were, in the Atlantic, in the centre of which there is the still water of the *Sargasso* or *Grassy Sea*. This area, so called from the vast accumulation of the *Sargassum bacciferum* and other floating sea-weeds, swarms with a life, vegetable and animal, peculiarly its own, and presents one of the most remarkable features in the geography of the Atlantic.—Following the southward flow from the Azores, and the south-easterly flow from the south coast of Ireland, against which a minor current (*Rennel's*) from the Bay of Biscay impinges and recoils, there arises a new and increased stream, which holds onwards to the African continent. Of this current, the eastern portion sets in through the Strait of Gibraltar to the Mediterranean, while the western trends southward, and becomes the *North African* and *Guinea Current*. This stream, from 150 to 180 miles broad, hugs closely the coast, and for a long part of its course flows in contact with, but counter to, the Equatorial Current, with whose waters it is supposed ultimately to mingle in the South Atlantic.

161. The next and last great current of the Atlantic to which our limits will permit us to advert, is the *Arctic*, Labrador, or main cold-water stream from the north. Set-

ting strongly down the eastern coast of Greenland, it partly doubles Cape Farewell, where, augmented by the Davis Strait Current, it holds southward to Newfoundland. Arriving at Newfoundland it sends a branch through the Strait of Belle Isle to the St Lawrence, while the main portion continues its course till it meets the Gulf Stream in the neighbourhood of Newfoundland. Here its waters divide. Part flow to the south-west along the shores of the American continent, forming the *United States Counter-Current*, the line of contact between which and the heated waters of the Gulf Stream to the eastward is so abrupt, and so well marked to great depths, that it is known as the "*Cold Wall.*" The main body sink downwards and continue their southward course below the waters of the Gulf Stream; and after sending off minor branches into the Caribbean Sea and the Gulf of Mexico, in the form of under-currents, they are finally lost in the general southward movement of the deep-sea waters of the tropical regions of the Atlantic.

162. In the more limited and land-locked area of the Indian Ocean, the constant currents are few, and the periodical numerous and important. The *Equatorial* is less defined than in the Atlantic, and consists of a westward tendency of the tropical waters towards the coasts of Africa, where, divided by the large island of Madagascar, one branch sets down with considerable force, and forms the *Mozambique Current;* while another, broader but feebler, trends southward, again to be united with that from the Mozambique Channel. The combined stream, now from 90 to 100 miles broad, with a temperature 7° or 8° above that of the ocean, and with a velocity of 60 or 80 miles a-day, sets in towards the Cape of Good Hope, and constitutes the *Agulhas* or *Cape Current.* Of this current, one main branch, doubling the Cape, flows northward into the Atlantic as far as St Helena—where, meeting the Guinea Current, it is deflected westward, and merges into the Equatorial of that ocean; whereas another portion, obstructed by the Agulhas bank, is turned back, and, combining with the connecting flow from the Southern Ocean, constitutes the important *Counter-Current* of the Indian Ocean. We say "important" counter-current, for it flows along the direct route to Australia, and with a velocity (after leaving the Agulhas bank) of nearly fifty miles a-day—a motion which,

though gradually declining, is still sensibly felt more than midway between the Cape and Tasmania. North of the equator, the currents and surface-drifts of the Indian Ocean are regulated by the monsoons, and vary, of course, with the seasons; while in the Red Sea, Arabian Sea, Persian Gulf, and Bay of Bengal, they set in and out with the local winds, and often change in a very complicated and capricious manner.

163. The currents of the Pacific are coextensive with its greater area, but are less decided in their courses in consequence of the numerous obstructions presented by its reefs and islands. They are less known than those of the Atlantic and Indian Oceans, and their investigation is greatly complicated by the frequency of counter-currents, surface-drifts, and local gyrations (Gr. *gyros*, a circle). The Pacific being all but excluded from the Arctic Ocean, it is to the interchange between the cold waters of the Antarctic and the warmer waters of the equator that we must look for the primary impulse of its currents. Beginning with the Antarctic, to which it opens broadly, we have first the *Drift Current* of that ocean setting in towards the north-north-east, then north-east, and lastly towards the east-north-east, till it nears the coast of Chili, where it divides, sending one branch south along the coast to form the *Cape Horn Current*, and another northwards to form the *Peruvian Current*, so remarkable for its cold stream along a coast of torrid temperature. This Peruvian, Chili, or "Humboldt's Current" (as it is sometimes called, after its first investigator), has a temperature, along more than 400 miles of its course, 12° or 14° below that of the surrounding atmosphere, and 8° or 10° below that of the ocean through which it flows. As it holds on to the north it gradually becomes warmer and inclines to the west, till in 20° south latitude it turns fairly to the westward and merges into the great *Equatorial Current* of the Pacific. This vast current, occupying the entire torrid zone, and hurried forward in its westerly flow by the trade-winds, sweeps boldly across from South America on the one hand to the Indian Archipelago on the other. As it proceeds, it sends off a few minor streams to the north and south, which become *counter-currents*, but the main mass holds onward to the Indian Islands, where it is broken up into several sections, and becomes further complicated by

the *monsoon drifts* of that region. One main portion, however, sets southwards with its warm waters along the coasts of Australia, under the name of the *New South Wales Current*, and enters the Antarctic Ocean; while another, still more decided, trends northward of the Philippine Islands, and becomes the well-known *Japan Current*, or *Black Stream* of the Pacific—its clear deep-blue waters being darker than those of the great ocean through which it flows. This last current, like the Gulf Stream of the Atlantic, which it greatly resembles in its course and character, carries the warm waters of the equator to the Northern Pacific; but having but a partial opening into the Arctic Sea by Behring Strait, it sweeps round the Aleutian Isles and the shores of Russian America, and returns again, with diminished temperature, to the torrid zone. As it proceeds along the shores of Oregon and California it begins to bifurcate, one branch trending westward into the ocean, and another holding still southward and merging into the waters of the *Mexican Current*. This current, which flows along the coasts of Mexico and Central America, is an alternating rather than a constant one—depending on the monsoons of these coasts, and setting south-eastward during winter, and north-eastward during the opposite half of the year. Besides the preceding, other minor currents have been noticed in the Pacific, as the *Carolinian Monsoon Current*—an alternating flow depending on the influence of the Indian and Chinese monsoons; the *Okhotsk Current*—an easterly set of the waters of that sea, arising from the south-east and easterly winds that prevail there during the summer; the *North Equatorial Counter-Current;* and *Mentor's* (after the Prussian surveying-vessel of that name) or the *South Equatorial Counter-Current.* These, however, and others of less note, are but partially known; the numerous islands and reefs of the Pacific not only interrupting the regular flow of the major currents, but rendering the minor ones more complicated and less decided in their directions.

164. Such are the principal *constant* currents of the ocean—the *periodical* and *variable* being too multifarious and local for the limits of a general outline. And yet, though local and limited, we know, from recent soundings, the important influence they exercise on the life of the deeper

ocean, according as their temperature rises above or sinks below icy coldness. In whatever character they appear, these currents are all-essential to the equilibrium and uniformity of the ocean. Excessive evaporation in the torrid zone is instantly counterbalanced by an influx from the temperate and frigid. The heated waters of the equator are modified by the colder currents from the poles; while the warmer and lighter waters of the equator flow over to temper the rigours of the polar seas. The salter and denser water of one area subsides and flows off as an under-current to some fresher region; while the fresher and lighter flows in from above to supply the deficiency. The heavier ever descends and the lighter ascends; and thus, vertically as well as horizontally, an incessant circulatory and equalising system is established throughout the expanses of the ocean. The colder ever flowing to the warmer and the warmer to the colder, their influence also extends to that of the lands against which they impinge, and thus additional warmth and moisture are borne to one country and refreshing coolness to another. Climate, and consequently terrestrial life, vegetable and animal, are modified by these currents; and in all likelihood they play equally important parts in the distribution and arrangement of the life of the ocean. Some course in shallow streams, and others press forward as deep and impetuous rivers—here arresting the progress of icebergs, that drop their burden of boulders and gravel on one zone, and there fostering the growth of foraminifera, corals, &c., that drop their exuviæ and rear their structures in another zone equally definite and restricted. Besides these great natural functions, they often subserve the purposes of navigation and commerce; and though the steam-ship has rendered the mariner less dependent on winds and tides and currents, he still skilfully seeks to avail himself of the favouring stream of one current, and to avoid the opposing influence of another.

RECAPITULATION.

165. The motions to which the waters of the ocean are generally subjected are waves, tides, and currents. Waves are produced by the friction and impact of the winds, and

occasionally by earthquake commotions. Wind-waves vary from a mere ripple of the surface to billows 10, 20, 30, and 40 feet in height; earthquake-waves have been known to rise higher, and, rolling in with greater impetus, they are more destructive.

166. Tides are produced by the attraction of the moon and sun acting on the mobile waters of the ocean. In consequence of the earth's rotation there are two tides a-day; and owing to the moon's revolution, and her position as regards the sun, there are two spring-tides and two neap-tides a-month. The moon being the nearer luminary, her attraction or tide-wave compared with that of the sun is as 100 to 38; and from this cause also the difference between spring-tide and neap-tide in any locality is as 7 to 3.

167. The currents of the ocean depend upon the unequal temperatures and densities of its different regions — the colder and warmer, the denser and lighter, the salter and fresher, incessantly tending to interchange and equilibrium —and upon the local impulse communicated to the surface of the waters by winds blowing in definite directions throughout the year, the movement thus set up necessarily drawing the surrounding waters into the general circulation. These currents are either constant, periodical, or variable: the constant depending on the primary and established relations of the earth; the periodical, on monsoons, tides, and sea and land breezes which occur in certain seas at stated seasons; and the variable, or local winds, melting of ice, river-floods, and other similar contingencies. Wherever the equilibrium of the ocean is disturbed by inequality of temperature, of density, or of surface-level, there currents will be established: and these will be constant, periodical, or variable; swifter or slower; surface or deep-sea; hotter or colder,—according to the nature and amount of the disturbing inequality.

X.

THE WATER—ITS RIVERS AND LAKES.

168. HAVING directed attention to the Water, as manifested in the larger expanses of oceans and seas, we now turn to its minor exhibitions in springs and streams, rivers and river-systems, lakes, and lacustrine areas. In the former instance the waters were truly oceanic, and characterised by their *saltness*; in the present instance they are more terrestrial, if we may so speak, and characterised, for the most part, by their *freshness*. They belong, however, to the same

Circulation of Water.

great aquatic system. The vapour elaborated from the ocean ascends invisibly and diffuses itself through the

atmosphere, where, subjected to colder currents, it is condensed, and becomes visible in clouds, mists, and fogs. Receiving further condensation through greater cold or electrical agency, it returns again to the earth in the form of dew, rain, hail, sleet, and snow. When in the atmosphere, water belongs to the domain of Meteorology; when it returns to the earth, it comes once more within the province of the Hydrographer, who tracks it in spring, stream, and river to the ocean. The circulation of water is incessant: now in the ocean, now in the atmosphere, now in the tissues of plants and animals, now in the crust of the earth, now coursing its surface, and anon in the ocean—again to repeat the same circuit, and this without intermission while the present relations of the universe endure.

Springs—their Origin, Characteristics, and Functions.

169. The water that falls on the surface of the land is partly and mainly carried off in runnels, partly by evaporation, partly supplies the wants of plants and animals, and partly sinks into the soil and rocky strata. Percolating the rocks, it collects in chinks, fissures, and other cavities; or, meeting in with some impervious bed, it accumulates in the porous strata above, and there forms extensive sheets of subterranean water. In virtue of the great law of gravity, water is ever tending to lower levels; and thus what gathers in the higher portions of the crust finds its way, in process of time, through rents and crevices, and, gushing forth, holds on its course to the valleys below. Where there are no impervious beds in the higher lands to intercept its downward tendency, it often percolates to vast depths, and far below the surface of the adjacent valleys; but sooner or later it is arrested by some obstructing stratum, and there, in obedience to hydrostatic pressure, it bursts forth through the nearest outlet, and rises to the surface with a force proportionate to the height of the accumulated waters. In whatever manner water may accumulate within the crust, or find its way again to the surface, the outlets are known as *springs;* and these springs occur in all countries and at all levels—some issuing with force even from the bed of the ocean. It is usual to speak of them as surface springs and deep springs, as perennial, intermittent, hot,

cold, mineral, and the like—characteristics, the consideration of which belongs more, perhaps, to Geology than to Physical Geography.

170. It may be noticed, however, that *surface springs* are those which issue from superficial beds of sand, gravel, and the like, and being immediately dependent for their supplies on the amount of rainfall, are often very feeble or altogether dry in summer, though gushing forth copiously during winter. *Deep-seated springs*, on the other hand, uninfluenced by summer droughts or winter rains, flow steadily at all times—though, generally speaking, the great majority of springs are more or less affected by the seasons. *Perennial springs*, as the name implies, are those that flow year after year without signs of abatement. They are evidently deep-seated, and many that were celebrated by the ancients gush as copiously now as they did thousands of years ago. *Intermittent*, on the other hand, are those that well forth at one period, and at another stop suddenly, and seemingly in a capricious manner. They are no doubt connected with subterranean reservoirs, whose waters alternately sink beneath and rise above their outlets; and this may be occasioned by sudden droughts and rainfalls; by the expansion and escape of steam and gases, by the ebb and flow of tides, and other kindred causes. Surface springs generally vary in temperature with the seasons; deep-seated ones, being beyond these influences, are equable at all times.

171. It was stated in pars. 21, 22, that the earth's crust, at the depth of 80 or 90 feet, is unaffected by summer's heat or winter's cold; but that below this depth the temperature went on increasing at the rate of 1° Fahr. for every 60 feet of descent. Springs whose sources are above this invariable stratum will therefore fluctuate in temperature according to the season of the year; those that ascend from beneath it will gradually increase in heat—the deeper being the hotter. *Cold springs* generally flow from chilled mountain sources; *hot springs*, on the other hand, arise either from vast depths, or are situated in the neighbourhood of volcanic action. Thermal and hot springs (hot even beyond the boiling-point of water, and accompanied by violent jets of steam) occur abundantly, and on a gigantic scale, in Iceland, the Azores, Central Asia, New Zealand, the Yellow Stone district in North America, and other volcanic regions; they occur also

in Britain, the Pyrenees, Germany, Austria, and other countries far removed from any centre of volcanic activity. Like ordinary springs, hot springs are either perennial or intermittent; perennial, like those of southern France and the Pyrenees, that have flowed without abatement since the time of the Romans—and intermittent, like the Geysers ("roarers") of Iceland and New Zealand.

172. The waters that percolate the earth being of different temperatures, and often containing carbonic acid and other gases, act chemically, less or more, on the rocks through which they pass. In this way they become *mineral springs*—that is, hold in solution various mineral ingredients, which are either deposited along their courses on land, or borne onward to the ocean. There is no such thing as absolutely pure water issuing from the crust of the earth—every spring bearing its quota of mineral or metallic matter. Some, for example, are saline, or contain salt; some chalybeate, or contain iron (*chalybs*, iron); some siliceous, or contain flint (*silex*); some calcareous, or contain lime (*calx*); while others give off sulphurous vapours, or are impregnated with the salts of various minerals and metals. Such are the sulphuretted waters of Harrogate, the brine-springs of Cheshire, the borax-springs of Tuscany, the travertine or lime-depositing waters of the Anio, the siliceous hot springs of Iceland and the Azores, and thousands of others that occur in almost every country. To the same category also belong escapes of steam, hot mud, and the like, so frequent in volcanic districts; and in the same way may be ranked discharges of gases, naphtha, petroleum, and so forth, which generally come to the surface in connection with water, and are seemingly dependent on its percolating and hydrostatic power.

173. Insignificant as springs may individually appear, they perform in the aggregate most important functions in the economy of nature. If the waters as they fall from the atmosphere were immediately carried off by surface runnels, the earth would at one time be flooded, and at another parched by destructive droughts. Sinking, however, into the soil, and diffused through its mass by capillary attraction, percolating the crust, and accumulating in its fissures and porous strata, this water is stored up, as it were, for future use, and given out by springs in moderate and continuous supplies. These springs are the great vivifiers of

external nature, supplying one of the main wants of animal life, and clothing even the desert around them with verdure and blossom. They are also the fountain-heads of our streams and rivers, whose channels, but for this incessant discharge from the earth, would often be reduced to a mere succession of stagnant pools, instead of flowing, as they now do, with never-failing currents. Ever silently seeking their way down through the rocky strata, these springs dissolve some minute portion, and carry it to the ocean, there to compensate for the abstraction of mineral ingredients by the plants and animals that inhabit its waters. Acting chemically, this internal permeation of water is evidently connected with the formation of mineral crystals and metalliferous veins, and possibly with that greater metamorphism of rock-masses by which strata of one nature are in process of time converted into strata of another and very different nature.

Streams—their Origin, Characteristics, and Functions.

174. *Streams*, as already explained, are formed by the union of several springs, and by the union of one stream with another, till, increasing in breadth and volume, they assume the character of rivers. When mainly dependent on springs (though augmented by rainfalls), they are said to be *permanent;* but when arising solely from rainfalls, melting of snow, and the like, they are *temporary*, and often of short duration. Permanent streams are usually distinguished, according to their dimensions, as *rills*, *streamlets*, *brooks*, *rivulets*, &c. (each country having its own expressive term for such distinctions), and their currents form *ravines*, *glens*, *gorges*, *valleys*, and other descriptive excavations. Temporary streams, on the other hand, are little noticed save in regions subjected to periodical rains, their dry courses being known as *nullahs* in India, *wadies* in Arabia, *creeks* in Australia, and so on in other localities. Streams occur in all countries, but fewest and least, of course, in rainless latitudes. Their great headquarters are the slopes of mountain-chains and the outer margins of valleys, and there they impress on the country geographical features and geological relations peculiarly their own. Coursing down

the mountain-sides with headlong speed, they form ravines, gorges, and waterfalls—their excavating power depending primarily upon their volume and velocity; and, secondarily, on the nature of the materials to be eroded. The aggregate amount of debris brought down by streams and torrents is enormous; and one has only to cast his eye over some lofty mountain-slope to see how deeply it is scarred and seamed and furrowed by these restless and resistless agencies. In fact, the great diversity of mountain scenery depends on this erosive power of water — all the hills and highlands depending less for their present outlines on the igneous forces by which they were upheaved, than on the meteoric and aqueous agencies to which they have been subsequently subjected.

175. Streams, like springs, subserve important purposes in the economy of nature. They constitute a great network of drainage for the land—carrying off superfluous moisture, and preventing its accumulations in bogs, swamps, and morasses. They are at once the carriers and distributors of water—dispensing in measured supplies the heavy rainfalls, melting snow and ice of the highlands, to the less rainy regions of the plains below. Geologically, they are incessant workers of change,—here cutting out ravines, glens, and gorges—there filling up lakes with the eroded material; here wearing deeper channels for the further drainage of swampy lowlands, and there assisting in that universal transport of sediments to the ocean, which is destined to become the strata of future lands. Man, too, ever early locates himself on their banks, employing their perennial supplies in the wants of his home, in the irrigation of his fields, or as a cheap and effective agent in the turning of his machinery.

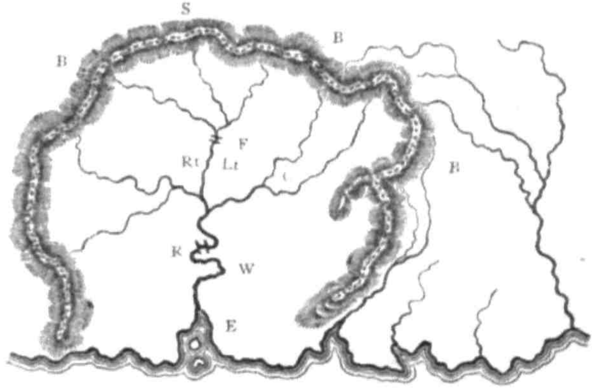
Rivers—their Origin, Characteristics, and Functions.

176. As streams are formed by the union of springs and minor runnels, so rivers are formed by the union of streams. In general they have their origin in some notable spring, lake, morass, or melting glacier, far up among the mountains. This infant current, augmented by the accession of other springs, becomes a main stream; and this stream, by

the influx of other *affluent* or *tributary* streams, very soon assumes the dimensions of a RIVER. A river is thus said to have its *head* or *source* in some higher region; to flow along a certain *course;* to wear out for itself a *bed* or *channel*, whose margins form its *banks;* to receive certain affluents whose junctions with the main stream form their *confluence;* and ultimately to discharge its waters in some lake, sea, or estuary by a *mouth* or *mouths*. In other words, every river has a *rise*, *flow*, and *fall*, which form the essential features of its existence. Where the ground, in the ultimate part of a river-course, is low and level, the accumulating waters often discharge themselves by several branches, and form a *delta* (par. 107), as in the Nile, Niger, Indus, Ganges, &c.; and such deltas may be either marine, lacustrine, or fluviatile, according as the rivers flow into the sea, a lake, or another larger river. Where the tides and river-currents contend, there frequently accumulates across the entrance a spit of sand or gravel, known as a *bar;* and these bars are serious impediments to the navigation of some of the finest rivers. As all rivers flow from higher to lower levels, the terms *up* and *down* have reference to this natural condition; and as a spectator descends with the current, the *right bank* lies on his right hand, and the *left bank* on his left. When he ascends, however, this order is reversed—the right bank being then on his left hand, and the left bank on his right.

177. The whole extent of country drained by a river and its tributaries is spoken of as the *basin* of that river (basin of the Thames, basin of the Tay, &c.); and this naturally, from the hollow or valley-shaped aspect which such districts usually assume. The ideal line connecting the sources of all the affluent streams defines such a basin, which is often of a very irregular and capricious form. As streams unite to form rivers, so several river-basins may descend towards the larger depression of some inland sea; and thus geographers speak of the "basin of the Baltic," the "basin of the Mediterranean," and, carrying the idea still further, even of the "basin of the Atlantic." As the great oceans form the ultimate receptacles for all the rivers (with one or two exceptions), the river-basins that descend to any ocean constitute what is termed the *river-system* of that ocean; and thus we have the Arctic System, the Atlantic System,

the Pacific System, and the System of the Indian Ocean—together with the Aralo-Caspian System and the minor basins of Utah, the Mexican table-land, and the plateau of Bolivia, whose streams are strictly continental, and confined to these areas. The line or ridge that separates one basin



RIVER-BASIN.—B, B, B, Boundary of Basin or Watershed; F, Falls; R, Rapids; W, Windings or Links; E, Eyots or River Islets; Rt, Right Bank; Lt, Left; S, Source; C, Confluence of two Tributaries.

or system from another basin or system is termed the *water-shed* of these basins (or *waterscheid*, if we affect a German derivation)—all the springs and streamlets "shedding or parting off" as if from the ridge of a house to their respective areas. Though hills and mountains generally form the boundaries between river-basins, it does not follow that watersheds should always consist of elevated ground—a few feet of fall being sufficient to determine the current in either direction. The low ridge that thus separates the streams of different basins is spoken of as a *portage* (Fr.), from the fact that goods and boats are frequently carried across from one stream to another; and thus, it may be, completing the passage by water from one side of a continent to another. The term is also applied, in a more general sense, to any portion of a river rendered unnavigable by falls and rapids, and thereby causing the carriage by land of the cargo, &c., till the obstructions are surmounted.

178. Such are the usual *terms* employed by geographers in treating of rivers; the *characteristics* of the rivers themselves—that is, their rise, course, length, volume, depth, velocity, capability of navigation, and the like—require more detailed consideration. As to their *rise*, it has been already stated that it generally takes place in some upland spring, lake, or morass, and not unfrequently in the melting terminus of some descending glacier. Many of these springs, especially those issuing from chasms and caverns in limestone districts, are often of considerable magnitude, being, in fact, full-flowing streams when they make their appearance at the surface. Mountain-lakes, being the recipients of springs and other runnels, become in like manner copious sources—the streams that flow from them being already rivers in miniature. The same may be said of morasses and high swampy tracts, which, being saturated with springs and rainfall, discharge at once regular and continuous streams. Glaciers and melting snows, though less frequent as sources, are important regulators of supply in the regions where they occur—their waters flowing freest when the summer's heat has most diminished the lowland streams. Whatever their origin—and it must be confessed that the exact sources of many of our larger rivers are unexplored and undetermined—their *courses* are primarily directed by the general slopes of the continents. In the Old World, the great slopes being north and south, the principal rivers flow in these directions, just as in the New World their courses are easterly and westerly, in obedience to the relief of that continent.

179. But while this is true, and necessarily so, as regards the main slopes, it should be borne in mind that there are many causes tending to modify the courses and directions of rivers. Among these, for example, may be noted the *strike* or direction of the secondary hills and spurs, which are usually at right angles to the main chains, the occurrence of lines of fracture in the crust, the passage from one formation to another whose strata lie in a different direction, and the alternation of softer and harder beds—the current readily excavating its channel in the line of the former, but obstructed and turned aside in another direction by the latter. All these, and many other circumstances, concur to give streams and rivers very irregular courses—

winding and bending, turning and re-turning, but still guided in the main by the primary slope of the region. As to the *length* of their courses, that will depend primarily upon the extent of the region through which they flow—the larger area giving scope to the longest river; and, secondarily, upon the bendings and windings to which they may be subjected. The *direct course* between the source and outlet of a river may not exceed two hundred miles, and yet its absolute course, through all its doublings and windings—its *development*, as it is termed—may amount to a thousand. This absolute length gives no true idea, however, of the importance of a river, either in nature or to navigation—its value mainly depending on the permanence of its volume, its depth and velocity.

180. The *volume*, size, or magnitude of a river—that is, the quantity of water which its channel contains—depends on many collateral circumstances, but chiefly on the extent of country drained by its affluents. There may occasionally be some peculiarity of basin as regards rainfall, melting of snow, and the like; but, generally speaking, the greater the area over which the tributaries ramify, the greater the quantity of water brought to the main trunk or channel. In temperate latitudes this volume is somewhat lessened in summer and increased in winter; but on the whole the supply is pretty equable and permanent. Sudden excesses, arising from heavy rainfall, rapid melting of snow in spring, and the like, are merely temporary, producing what are termed *floods*, *freshets*, and *débacles*. In tropical countries, on the other hand, where the rains fall and the snows melt only at stated seasons, these floods assume the character of regular and *periodical inundations*. And where the rains fall in the low countries at one period, and the far-off mountain-snows melt at another, there may be two such inundations occurring with wonderful regularity both in time and amount of overflow. Again, where the sources of a river lie near the equator and its outlet in the temperate zone (as in the case of the Nile), a considerable time must elapse between the equatorial rainfall and the deltic inundation; and the length of this lapse will depend partly on the windings of the river, and partly on the slope and freedom of the channel. In the preceding instances, whether subjected to irregular floods or periodical inundations, the

river itself is always more or less *permanent*; but in some regions, as Australia and South Africa, many of their so-called rivers are merely *temporary*, being roaring impetuous torrents during the rains, and a succession of stagnant pools ("creeks") and dry shingly reaches during the season of drought.

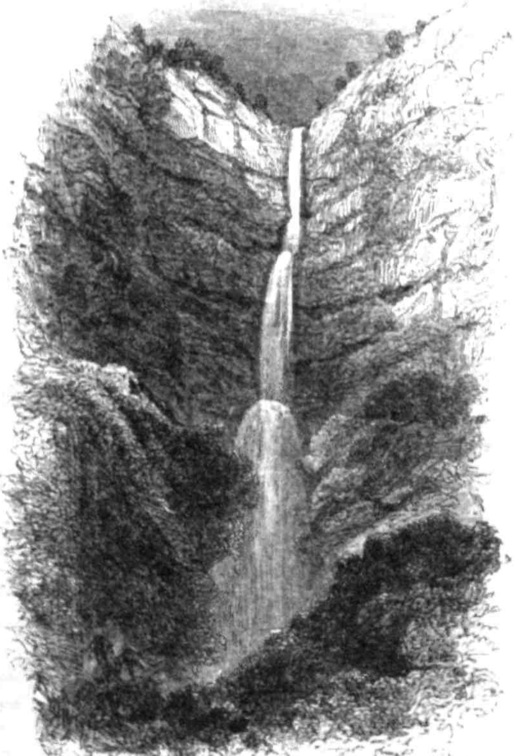
181. The *velocity* of a river depends mainly on the slope or declivity down which it flows, partly on the nature of its channel, according as this may be straight or winding, deep and narrow, or wide and obstructed by rocks and shoals, and partly also on the amount or volume of its current. As all rivers descend from higher to lower regions, and many of them from very elevated sources, they may be said to have an upper, middle, and lower course,—the *upper* being characterised by rapidity of stream through gorge and glen and waterfall; the *middle*, by less velocity through rapids and cataracts; and the *lower*, by a quiet steady flow through level and alluvial plains. Other things being equal, the deeper the river, the more rapid the current,—the greatest velocity being in the centre of the stream, and a little below the surface, where there is least retardation from friction on the sides and bottom of the channel. The velocity of rivers is an all-important consideration in their geographical, geological, and commercial relations. The more rapid their currents, the less the irrigating effect, and the greater the geological effect on the countries through which they flow; and in proportion as their velocity increases, so their fitness for the purpose of navigation is diminished. Formerly a descent of more than 1 foot in 200 was considered unnavigable; and though the power of steam has enabled man to contend with higher velocities, it is still the velocity of current more than the depth of water that renders a river unavailable as a means of internal communication.

182. Geologically, the cutting as well as transporting power of rivers is greatly aided by the rapidity of their currents; hence the effect of mountain torrents compared with the quiet sluggish flow of the lowland river. It has been calculated, for example, that a velocity of 3 inches per second will tear up fine clay, that 6 inches will lift fine sand, 8 inches sand as coarse as linseed, and 12 inches fine gravel; while it requires a velocity of 24 inches per second

to roll along rounded pebbles an inch in diameter, and 36 inches per second to sweep angular stones of the size of a hen's egg. During periodical rains and land-floods the currents of rivers often greatly exceed this velocity; hence the tearing up of old deposits of gravel, the sweeping away of bridges, and the transport of blocks many tons in weight —an operation greatly facilitated by the circumstance that stones of ordinary specific gravity (from 2.5 to 2.8) lose more than a third of their weight when immersed in water. It must ever be remembered, however, that the eroding power of a river depends very much on the nature of the rocks through which it flows: one traversing a country consisting of the softer rocks—sandstones, clays, and shales—rapidly deepening and widening its channel; while another, passing over the harder rocks—granites and greenstones—effects little or no change for ages.

183. As has been stated, *cataracts* and *waterfalls* usually occur in the upper courses of rivers, and are produced by the stream either passing from a higher to a lower platform of country, or by its cutting through harder and softer rock—the softer yielding to the current, and the harder resisting, and causing it to pass, by one bound, or by a succession of bounds (see p. 164), into the chasm below. Dykes of basalt, greenstone, felstone, and the like, or beds of conglomerate and siliceous limestone, are generally the rocks over which the current has to fall, or through which it has to force its way. Among the more stupendous waterfalls in the world may be noted that of the *Yosemite* valley in California, where a stream as large as the Thames at Richmond is said to make a single leap of not less than 2100 feet; *Niagara*, between Lakes Erie and Ontario, where the river, 3225 feet wide, is divided in two by Goat Island, and falls on the one side sheer 162 feet, and on the other 149 feet; *Victoria Falls*, on the Zambesi, where the river, 1000 feet wide, is suddenly swallowed up in a narrow perpendicular cleft 100 feet deep; *Kaieteur*, on the Potaro, in British Guiana, where the stream, 134 yards wide, has a total fall of 822 feet—741 of which is a sheer perpendicular descent into a vast seething caldron below; those of the Livingstone and Congo, described by Stanley, in Africa; *Schaffhausen* on the Rhine, 72 feet; those of the *Glommen* in Norway; those of the *Clyde* in Scotland; and

some lofty threads of water (1000, 1400, and 2000 feet) which descend from the Alps and Pyrenees. Though picturesque, the effect of rapids, cataracts, and waterfalls is to bar all navigation, and render inaccessible the interior of a country, however gigantic its lakes and noble its rivers.



Tseen-chang-yan Waterfall, China.

184. The *depth* of rivers is as various as the circumstances under which they occur, though, generally speaking, the greater the volume of water, the deeper the channel of

excavation. In their upper and middle courses, the stream, being for the most part through steep rocky excavations, is of no great depth; but in the lower and slower portion the waters accumulate and deepen as they proceed. The *outlet*, or *embouchure* (Fr.), as it is frequently termed, depends altogether upon the conformation of the country. Some rivers discharge themselves at once and by a single mouth into the ocean; others into an estuary, and are consequently affected for a certain length by the flux and reflux of the tides; while others, again, creep sluggishly along, branching and bifurcating through their swampy deltas, till they find their way into the sea by several main mouths. Seeing that the condition of rivers is so exceedingly varied, their *facilities for navigation* will depend in each case on the nature of the outlet as accessible from sea and free from bars and banks, on depth and volume of water, and on the velocity of the current. Length of course and volume of current may be obstructed by rocks and shoals; depth of volume may be rendered unavailable by shallow bars and shifting sandbanks.

River-Systems—Oceanic and Continental.

185. It will be seen from what has been stated respecting the characteristics of rivers, that each has its own individuality, and that this individuality depends in the main on the geographical position, extent, and superficial configuration of its basin. To give an account of these basins would be to describe in detail the rivers that traverse the surface of the globe—a subject which extends beyond our limits, and belongs more especially to hydrography and general geography. All that our outline will permit is the arrangement of the basins into SYSTEMS, and a notice of some of the more remarkable rivers that belong to each system. As all the affluent streams of a river belong to one basin, so all the river-basins that descend to the same ocean-basin—whether directly, as the Niger to the Atlantic, or intermediately through some inland sea, as the Nile to the Atlantic through the Mediterranean—belong to the river-system. In this way we have four great *oceanic river-systems*—the Arctic, Atlantic, Pacific, and Indian; and one

unlike those of Siberia, they are connected with a labyrinth of lakes, a feature peculiarly characteristic of the northern section of the American continent.

187. The *Atlantic System*, as the name implies, embraces all those rivers that find their way directly or intermediately into the great basin of the Atlantic from the slopes of the adjacent continents. It necessarily arranges itself into four sections — the European, African, North American, and South American, according as the rivers descend from either of these continents:—

1st, In the European section we have certain rivers that flow into the Atlantic directly, and others that enter it indirectly through the Baltic and Mediterranean. The chief of those flowing into it directly are the Elbe, Weser, and Rhine, from the western slopes of the Germanic plain; the Seine, Loire, and Garonne, from France; and the Douro, Tagus, Guadiana, and Guadalquivir, from the Spanish peninsula. The Rhine—the "beautiful Rhine" of the Germans—springs from Alpine glaciers at an elevation of 7650 feet, descends to Lake Constance (1250 feet), thence through the Falls of Schaffhausen to Basel (800 feet), and thence with a navigable course to the North Sea, which it enters by the largest of European deltas. The Rhine has thus a well-marked upper and lower course, a development of 600 miles, and a drainage of 65,000 square miles; the Loire an absolute course of 520 miles, and a drainage of 33,000 square miles; while the Tagus, the third in importance, has a length of 400 miles, and a drainage of 21,000 square miles. The principal streams that discharge themselves through the intermediate basin of the Baltic are the Neva, Niemen, Vistula, and Oder—all more or less obeying a north-westerly slope, and, like their recipient, ice-locked for a considerable portion of the year. Of these the Vistula has the greatest development and drainage — its length being 520 miles, and its basin 56,000 square miles. The waters that fall from the European side into the basin of the Mediterranean are—the Ebro and Rhone into the main sea; the Po into the Gulf of Venice; and the Danube, Dnieper, Dniester, and Don into the Euxine Sea. The Rhone rises among the Alps at an elevation of 5500 feet, and, having a natural course of only 500 miles, is necessarily one of the most rapid rivers in Europe. It has a drainage of 23,000

square miles, discharges itself by two main mouths, and, when in high flood, projects its current with such force that its fresh waters can be skimmed from the surface several miles out at sea. The waters that enter the Black Sea branch of the Mediterranean basin obey the great southern and south-eastern slope of the European continent. Of these the Don, Dnieper, and Dniester have comparatively gentle currents, and all in their lower courses flow through flat swampy plains. The Danube, the most important of the suite, rises in the Black Forest at an elevation of 2850 feet, has a winding course of 1496 miles, and an area of 234,080 square miles. Originating in the union of several mountain streams, it is first known as the Donau or Danube in the Duchy of Baden, from which it runs through an Alpine country to Ulm, and thence to Passau it traverses the plain of Bavaria. From Passau to Vienna it runs through a second hilly region, and the remainder of its course is generally through a flat country (except on approaching the rocky defile of the "Iron Gate") till its embouchure by three main mouths into the Euxine Sea. The Danube and its navigable tributaries, the Theiss, Drave, and Save, form important channels of internal communication for Eastern Europe—an importance that has been greatly enhanced by the adoption of steamers fitted to the peculiarities of their currents. Such are the principal rivers of Europe that fall directly or indirectly into the basin of the Atlantic. Lying in the temperate zone, and having their sources at no great distance from the ocean, their volumes are wonderfully regular and persistent, being merely liable to occasional floodings from excess of rainfall, or from sudden meltings of the snow in early spring. The extent and configuration of the continent prevents the formation of large and long rivers; but as the rapids and waterfalls are confined to their upper stages, the lower portions of their courses are in most instances easy of access and more or less navigable. Whether viewed as channels of drainage and irrigation, or as means of internal communication, these rivers constitute an essential feature in the physical geography of Europe. Flowing from the central region in every direction, they equalise the water-supply more than in any other continent, confer greater beauty and amenity on its surface, and afford at once a perennial supply and

an available mode of intercommunication to its busy populations.

188. The African section of the Atlantic system embraces all those rivers which flow from the western and northern slopes of that continent—the former discharging themselves directly into the ocean, the latter indirectly through the basin of the Mediterranean. Of those entering directly into the Atlantic, the Senegal, Gambia, Niger, Congo, Coanza, and Orange are the more important, though still but very partially known in their middle and upper courses. The Senegal and Gambia, which rise in the Kong Mountains, and have courses from 600 to 850 miles in length, form the conjoint basins of Senegambia, and are navigable to some extent. The Niger, one of the noblest of these western rivers, is supposed to have its sources in the northern slopes of the Kong Mountains, and, after a circuitous course of more than 1500 miles, during which it receives the Chadda and other large tributaries, enters by several navigable mouths the Gulf of Guinea. The Niger (Joliba or Quorra) drains an immense but unknown extent of tropical Africa; has a navigable middle course of many hundred miles, varying from one to six miles in width, and running at the rate of five and eight miles an hour; and possesses a low pestilential delta of 14,000 square miles, alternately choked with the rankest jungle-growth and overspread by inundation, which attains its height about the middle of August. The Gaboon and Ogowai are so far navigable, but are interrupted by rapids and cataracts, and remain unknown as to their tributaries and courses in the interior. The Congo and Coanza, also frequently interrupted by rapids and waterfalls, are comparatively unknown. The former, as has been shown by Stanley, is one of the noblest rivers on the globe, but rendered unfit for continuous navigation by these obstructions. Known in its middle course as the Livingstone, it receives many important tributaries, is of varied width, and ultimately issues from Lake Tanganyika, which, with many others (Bangweolo, Nyassa, &c.), occupies the central table-land south of the equator. The course of the Congo, though traversed by Stanley, still requires further exploration, especially its tributaries, which seem to flow through regions of unequalled luxuriance and fertility. The Orange or Gariep is unnavi-

gable, being alternately a large impetuous torrent during the rains, and a shallow shingly stream during the season of drought. The most important, and indeed the only African river that discharges itself into the Mediterranean, is the Nile—the most classical, and in many respects the most remarkable, river in the world. Flowing from the equatorial lake, Victoria N'yanza (3300 feet above the sea-level), as the Bahr el Abiad, or White Nile, it receives, after a considerable course, the Bahr el Azrek, or Blue Nile, from the Galla country, and lower down is augmented by the Atbara from Abyssinia — the conjoint stream flowing downward through Dongola, Nubia, and Egypt (a distance of 1200 miles), without receiving any additional accession of waters. Its total length from Lake Victoria is about 2300 miles, and its supposed drainage-basin not less than 1,000,000 square miles. Nothing is yet known with certainty of the feeders of the Victoria and other adjacent lakes, which in all likelihood derive their head-waters from the snowy regions of equatorial Africa; but the upper course of the main river is described by Captain Speke and others as flowing through a beautiful and fertile country; its middle course through Nubia is marked by a succession of low rapids or "cataracts," nine or ten in number; and its lower course having a fall of only two inches a-mile, the current flows gently through the plains of Egypt till its final discharge into the Mediterranean by the two main mouths which enclose its delta. This delta commences 90 miles from the sea, and has a coast-line of 187 miles between its main mouths, the Rosetta and the Damietta. In the plain of Egypt, which is from 2 to 18 miles in width, the current of the Nile, when not in flood, is about 2½ miles an hour, but in its delta branches the flow is almost imperceptible. The most remarkable feature in the Nile is the regularity of its annual inundation, which arises from the rainfalls dependent on the south-east trade-winds of the Indian Ocean. These rains falling heavily on the table-lands of Abyssinia and Upper Nubia, are rapidly borne down by the Blue Nile, Atbara, and other tributaries, to the slower current of the White Nile, which, unable to contain them, rises and gradually overflows the surrounding low country. In the upper or Abyssinian branches the river begins to rise in April, but at Cairo the flood is not perceptible till towards the summer

solstice. It then continues to rise for nearly a hundred days, and remains at its greatest height till the middle of October, when it begins to subside, and reaches its lowest point in April and May. So far as we have evidence, the annual period and amount of this inundation have remained unchanged for the last 4000 years. Its height in Upper Egypt is from 30 to 35 feet, at Cairo from 20 to 24, but in the northern part of the delta, where it spreads out over a wider area, it seldom exceeds 4 or 5 feet. The fine black slime or mud deposited by this inundation, and borne from the rocky table-lands and precipitous gorges of Abyssinia, has been the unfailing source of wealth and fertility to Egypt: and from its accumulation, in like manner, has arisen the formation and increase of the delta.

189. The rivers of South America constitute by far the most unique and gigantic section of the Atlantic system. Indeed, all the rivers of that continent obey its great eastern slope towards the Atlantic—the streams that flow down the abrupt and rainless counter-slope towards the Pacific being mere runnels fed by the melting snows of the Andes. In this case, we have at once area for development, supply from heavy rainfalls engendered by the moisture-laden winds of the Atlantic, as well as from melting snows and perennial springs, and breadth of volume arising from the flatness of the surface over which these rivers flow. Beginning at the south, the rivers of Patagonia are of little importance, being described as "of small magnitude, with few or no affluents, and making straight across the dry shingly terraces of that sterile region." North of this the great river-system commences, embracing the basins of the Plata, the San Francisco, the Paranahyba, the Tocantins, the Amazon, Orinoco, and Magdalena. The Rio de la Plata, whose drainage is estimated at 886,000 square miles, receives its affluents from very distant and different regions—the Salado, Vermejo, and Pilcomayo from the deserts and salinas of the Lower Andes—the Paraguay and Parana, two noble rivers, from the wooded slopes and verdant plains of the central regions—and the Uruguay from the low sierras and valleys of Southern Brazil. Some of these affluents, like the Paraguay and Parana, are navigable for hundreds of miles inland, and, on the whole, have deep and accessible channels, but are subject to periodical and destructive inundations. Their

united waters meet in the estuary of the Plata—a fresh-water sea, 180 miles long, and 120 broad at its entrance; but shallow and loaded with mud, whose discoloration is perceptible far out the Atlantic. The San Francisco, having a length of 1400 miles and an estimated drainage of 187,000 square miles; the Paranahyba, having a drainage of 115,000 square miles; and the Tocantins, or Para, of 284,000 square miles,—are strictly Brazilian rivers, rising among, and flowing between, the sierras of that country. Little is known of their sources, but they descend with considerable currents till they enter the lowlands that fringe the Atlantic, from which they are navigable for long distances inland. The Amazon, by far the largest river in the world—having a length of 3500 miles from its remotest feeder (the Apurimac) in the Andes to its union with the ocean, and an estimated drainage of 1,512,000 square miles—is that which gives life and character to the lowlands of tropical America. Entering the ocean by an estuary 200 miles long and 130 broad, its freshening influence is felt several hundred miles out at sea; while its main stream, though much impeded by mud-banks and islands, is navigable for 2000 miles inland. Its principal affluents on the right are the Zingu, Tapajos, Madeira, Purus, and Ucayali, which flow from the sierras of Brazil and the central region; and on the left the Rio Negro, the Japura, and Putumayo, which descend from the mountains of Parimé and the northern Andes. Many of these tributaries are largely navigable, and though treated as mere feeders of the Amazon, would be esteemed important rivers in the geography of other countries. The head-waters of the Amazon drain the entire circle of the middle Andes, almost connecting its stream by a low portage with the Paraguay on the south, and actually uniting it by the Casiquiare with the channel of the Orinoco on the north. Like other tropical rivers, the Amazon is subject to periodical inundation—its waters beginning to rise in December, being at their greatest height in March, and lowest in July and August. When in flood, its waters overspread an immense extent of country, which thus becomes alternately a fresh-water sea, and *selvas* teeming with the rankest tropical vegetation. The Orinoco—the last of South American rivers to which our space will permit us to advert—has a basin of nearly 300,000 square miles, and a navigable course at all seasons of

more than 1000 miles. Rising in the mountains of Parimé, it takes a circuitous course northwards and then eastwards, receiving on the one hand several important tributaries from the Andes, and on the other a number of smaller streams from the ranges of the Parimé. Increased by these affluents—the Guaviare, Meta, and Atures, on the left, and the Paraqua and Caroni on the right—it ultimately finds its way by a perfect labyrinth of mouths into the basin of the Atlantic. Its annual floods take place with great regularity—commencing about the end of March, and decreasing by the end of August. During high flood, thousands of square miles of the low flat basin are inundated to a depth of 30 feet—these flats, alternately flooded and covered with long rank grass, constituting the celebrated *llanos* of the Orinoco.

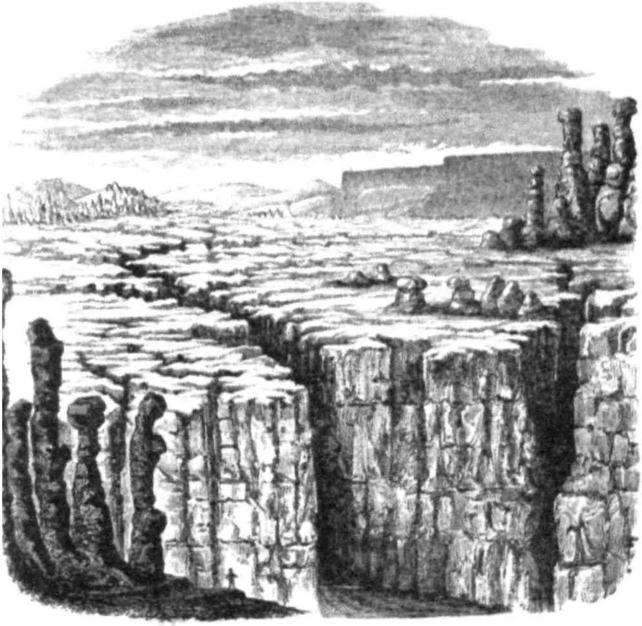
190. The river-systems of North America are governed by the disposition of the Rocky Mountains much in the same way as those of South America are governed by the Andes. The counter-slope of the Rocky Mountains, being less abrupt than that of the Andes, gives development to two or three streams of some importance on the Pacific side, but in the main the great river-basins are directed towards the Atlantic. The central plain that stretches from the Gulf of Mexico to the Arctic Sea being divided by a low watershed of 1300 or 1500 feet, a few rivers, as the Mackenzie and Coppermine, trend northward to the Arctic basin, but all the larger and more important lie south of this watershed, and belong to the Atlantic system. Of these the Rio del Norte and the Mississippi fall into the Gulf of Mexico; the St Lawrence directly into the Atlantic; and the Saskatchewan and Churchill into Hudson Bay. The Rio del Norte, which rises among the sierras of New Mexico, has its upper course through a desert region, in which it receives few affluents; but as it descends into the lower grounds it gains considerable accessions, and becomes a natural boundary between the United States and Mexico. Its drainage area is estimated at 180,000 square miles. The Mississippi ("father of waters") is by far the largest of North American rivers. Rising in the small lake of Itasca, on the verge of the middle table-land, at an elevation of 1500 or 1600 feet, it runs southward through the great central plain, receiving numerous accessions from either side, and, after a winding course of 3160 miles, falls

through a swampy delta into the Gulf of Mexico. Its main tributaries on the right or Rocky Mountain side, in which they take their rise, are the Missouri—a river even longer, larger, and having more affluents than the Mississippi itself—the Arkansas, having also many affluents, and the Red River; while on the left its chief tributary is the Ohio, with its numerous feeders from the western slopes of the Alleghanies. Between the Rocky Mountains on the west, and the Appalachians on the east, lies, therefore, the great conjoint basin of the Missouri, Mississippi, and Ohio, having an area of more than a million square miles; containing every description of soil and scenery—prairie, barren, and woodland; watered by innumerable streams and several navigable rivers; and possessing every variety of climate, from the coldly temperate highlands of Nebraska to the sub-tropical warmth of the Gulf of Mexico. The Mississippi, we have said, has a winding course of 3160 miles, but if the Missouri be taken as the main stream, its length is 4260 miles; while that of the Arkansas is 2000, and the Ohio more than 1000 miles. The breadth of the Missouri and Mississippi above their confluence is about half a mile, and the main stream downwards is little more. Though gentle, the current is by no means sluggish; and thus, during floods, from the melting of the snow in the higher latitudes, the rivers sweep downwards immense quantities of mud, drift-wood, and other debris. The Missouri is said to be navigable "from the Great Falls in the Rocky Mountains to the sea, a distance of 4000 miles; the Mississippi, from those of St Anthony, 2240; while the Ohio, being connected by a system of canals with Lake Erie, and thence to Lake Ontario, carries out a water-communication between the Gulfs of Mexico and St Lawrence." The delta of the Mississippi, which projects itself forward into the Gulf of Mexico, is a low and unhealthy region, nearly 14,000 square miles in area, and full of lagoons, creeks, and pestilential marshes. The St Lawrence, which forms the great water-highway to Canada, takes its rise under the name of the St Louis, far west in the central lake-region of North America. After uniting the lakes Superior, Huron, Erie, and Ontario, it issues from the last by the name of the Iroquois, and alternately contracting and expanding into lake-like reaches, it is known as the St Lawrence at Montreal, whence it

flows to Quebec, and thence by its long estuary into the Atlantic. Its drainage-basin is estimated at 297,000 square miles, of which 94,000 or more is covered by fresh-water lakes. Its estuary is 350 miles long, and 80 broad at its mouth, but, from its northward position, is frozen and ice-locked during the winter. The Saskatchewan and Churchill take their rise, in like manner, among the labyrinth of lakes that characterises the extreme northern plain of America, and, after flowing from lake to lake with irregular and tortuous courses, find their way to the North Atlantic through Hudson Bay. The basin of the Saskatchewan is estimated at 300,000 square miles, and that of the Churchill at 73,000, but a large portion of both is occupied by lakes and frozen morasses.

191. Encompassed as the *Pacific* is by the continent of America on the one hand, and by that of Asia on the other, its *river-system* is altogether peculiar, and disproportionate to the encircling areas. On the American side, from Tierra del Fuego to the Gulf of California, there is not a single stream of importance. From that point northward to Behring Strait the chief river of note is the Colorado, which rises among the sierras of New Mexico, and drains with its tributaries an arid and rocky area of 170,000 square miles, cutting its way through *cañons* or gorges, often of extreme depth, and ultimately falling into the Gulf of California. The chief cañon of the Colorado has for the greater part of 200 miles of its length nearly vertical walls from 2000 to 6000 feet in height. Next comes the Columbia, with its main tributary the Lewis, descending with impetuous current over waterfalls and cataracts from the Rocky Mountains, traversing the Oregon territory, and draining an area computed at 194,000 square miles; the Fraser, an equally rapid stream, rising among the ranges of the Rocky Mountains, and watering the wild but picturesque country of British Columbia. Finally, we have the Yukon, a large but little known river, draining the inhospitable uplands of Alaska for more than 2000 miles, 600 of which are said to be navigable by flat-bottomed craft, though much impeded by sand-shoals and islands. Abutting as the Andes and mountains of Mexico do upon the very shores of the Pacific, there is no space for the development of rivers; and it is only where the Rocky Mountains bend inland, and are flanked

by minor hill ranges, that the Colorado, Columbia, and Fraser make their appearance.



Cañon of Colorado.

192. On the Asiatic side of the Pacific the case is altogether different, the mountains from which the rivers descend being not only far inland, and thus affording ample area for development, but being, moreover, the recipients of abundant rain and snow fall. We have thus, descending the eastern slopes of Asia, the Amoor in Chinese Tartary; the Hoang-ho, the Yang-tse-kiang, and Tche-kiang in China; and the Menam and Mekong in Cochin-China—all first-class rivers—besides a vast number of affluents and minor streams that add to the fertility and importance of that region. The Amoor (Tunguse, "Great Water" of the Manchoos, Sagalhien, or "Black Water") rises high in the

Daurian Mountains, receives several large tributaries in its descent, and, after a course of 2400 miles, enters as a navigable river into the land-locked Gulf of Tartary, which opens on the one hand into the Sea of Okhotsk, and on the other into the Sea of Japan. It drains a computed area of 583,000 square miles; and from its navigable capabilities, safety of entrance, and relative position to Japan and Russian Siberia, is likely to become of considerable commercial importance. The great rivers of China—the Hoang-ho and Yang-tse-kiang—take their rise among the Kihan-shan and Kuen-lun Mountains, that buttress the plateau of Tartary, flow through an Alpine country, and after making their descent between the minor ranges of the Yun-ling and Pe-ling, wind with slow and steady flow through the plain of China into the Yellow Sea. The course of the Hoang-ho or Yellow River (so called from the colour of its waters) is estimated at 2300 linear, and its basin at 537,000 square miles; while the course of the Yang-tse-kiang is 2900 linear, and its drainage area not less than 548,000 square miles. Though their main mouths are wide apart, yet they may be said to fall into the same delta—their broad navigable streams being united throughout their lower courses by innumerable canals and natural channels. Indeed the whole country, from the southernmost branch of the Yang-tse, north to the Pei-ho or White River, which enters the Pe-che-le Gulf, is one alluvial flat, intersected by channels, canals, and embankments, and liable to be flooded and broken in upon by shiftings of the river-courses, and other similar changes. The burden of sediment which these rivers carry down to the shallow basin of the Yellow Sea is immense; and though frequently shifting their channels, and encumbered by sandbanks, they are navigable by vessels of considerable burden for 600 or 800 miles, and by smaller craft to perhaps double that extent. The Mekong is a large but little known river, rising in the mountains of Eastern Assam, flowing with a long course between the mountain-ranges of Cochin-China, draining, along with the Menam, an estimated area of 216,000 square miles, and falling into the Gulf of Siam or Cambodia by a many-mouthed delta.

193. *The river-system of the Indian Ocean* has three separate and independent sections—the Asiatic, the Australasian,

and the African, according as the rivers flow from either of these regions. The Asiatic embraces the Martaban and Irawady in Burmah; the Brahmapootra, Ganges, and Indus in India; and the Tigris and Euphrates in Persia and Asia Minor. The Martaban, Irawady, and other rivers of Further India, occupying the narrow valleys which lie between the parallel hill-ranges of that region, flow southward in long and comparatively straight courses. Very little is known of their sources or affluents; but the Irawady, which rises in the eastern range of the Himalayas, enters the Gulf of Martaban by a many-branching delta, is navigable for 500 or 600 miles, and though encumbered in its lower course by mud-banks and islands, is a channel of vast importance to the Burmese empire. During the season of inundation, which takes place between March and October, it spreads to a breadth of 3 or 4 miles, runs at the rate of 4 or 5 miles an hour, rises from 36 to 40 feet above its lowest level, and is heavily laden with sedimentary debris. There is, indeed, a great similarity among all the rivers of the Indo-Chinese peninsula, whether flowing like the Menam and Mekong into the Pacific, or like the Martaban and Irawady into the Indian Ocean; they have long straight courses, flow with considerable current through a country rich in tropical vegetation, and enter the sea by several mouths through low and gradually increasing deltas. The surface of the country presents great variety, according to Lieut.-Gen. Fytche, embracing rich alluvial valleys and fertile uplands; and perhaps no country in the world possesses a richer and more varied flora.

194. The Ganges, which rises at an elevation of 13,000 or 14,000 feet among the glaciers of the Himalaya, descends rapidly to the plain of India, and there flowing with gentle current, it receives numerous affluents from the southern slopes of its parent mountains on the one hand, and from the northern slopes of the Vindhya high grounds on the other, till it ultimately falls through a many-branching delta into the Bay of Bengal. The Brahmapootra ("offspring of Brahma") is formed by the union of two main streams, the Dzangho-chur, which has its origin in the northern slopes of the Himalayas, and flows eastward till its union with the Brahmapootra proper, which, descending from the distant recesses of the Tibetan mountains, runs southwards to-

wards Assam. After their junction, the united waters, under the name of the Brahmapootra, cut transversely the eastern Himalayas, and then, flowing south and westward with a volume considerably exceeding that of the Ganges, enter the delta of that river about 40 miles above the sea, but still maintain the individuality of their own channels. The conjoint area drained by these rivers and their affluents (several of which are larger than the Rhine) is estimated at 432,000 square miles, and their respective lengths, at 1980 miles. Like other tropical rivers, the Ganges and Brahmapootra are subject to annual inundations—the floods commencing in April, attaining their maximum about the middle of August, and continuing till October. They begin first to swell from the melting of the snows among the mountains, but before this influence has reached the low grounds these are widely under water from the periodical rainfalls. The quantity of water arising from these two causes and brought down by the Ganges and Brahmapootra is enormous, overspreading the plains for hundreds of square miles, and freshening more or less the whole upper area of the Bay of Bengal. The amount of sediment brought down by these rivers when in flood is also immense; and the whole delta, 200 miles in length and 180 broad at its base, with all its channels, creeks, lagoons, and mud-islands (*sunderbunds*), is clearly the offspring of this debris. Though liable to sudden shiftings during inundations, several of the branches of the Gangetic delta are navigable at all seasons for vessels of large draught; while the main stream can be ascended by smaller craft to the foot of the Himalayas. Though possessing a large volume, the Brahmapootra, from the rapidity of its current and the obstacles in its channel, is of less importance as a means of internal communication.

195. The Indus, the third great river of India, takes its rise in the highlands of Tibet, and after a precipitous course through the western Himalayas, descends into the plains, where it is augmented by the streams of the well-known Punjab, or Five Rivers. These affluents, like the main stream, are the offspring of the Himalayas, and drain a large expanse of upland as well as fertile lowland. After their union near the southern extremity of the Suleiman hills, the Indus receives no more tributaries of any note, but flows with gentle current through a somewhat arid country for

nearly 300 miles, and then forks into a delta 80 miles long by more than 100 broad at its base, discharging itself by many mouths, only three or four of which are navigable. The annual floods commence with the melting of the Himalayan snows in April, attain their greatest height in July, and terminate in September. The winding course of the river is nearly 2000 miles, and its estimated drainage 312,000 square miles; but, owing to the shallow and shifting nature of its mouths, it is navigable only by vessels of comparatively small burden. Lying open to the great tidal wave of the Indian Ocean, it has, like the Ganges, a rapid and dangerous *bore*, which ascends the main channels to a distance of 60 or 70 miles.

196. Australia, owing to its geological conformation, is singularly destitute of rivers—those descending the eastern counter-slope of its hills into the Pacific being mere streams, while those flowing from their western slopes seem to lose themselves in the great central and yet unexplored plains. The Murray, with a winding course of 1300 miles, and its tributaries, the Darling, Lachlan, and Murrumbidjee, are the only known rivers of note; and these, though roaring torrents during the rains, are often reduced to a mere chain of ponds and creeks in the dry season.

197. Of the African rivers that enter the Indian Ocean, geography knows too little as yet to offer anything like reliable description. The Zambesi is the largest and most important, draining an immense extent of inland country, of at least 600,000 square miles in area, which spreads out in plain-like expanses, reticulated by lakes and streams that flow during the periodical rains, but are desiccated and partially obliterated during the season of drought. On the whole, recent investigation seems to point to the interior of Central Africa as a plateau-shaped plain, deriving its main water-supply from rains, which form, for the most part, only temporary streams and lakes—the surplus being carried off by evaporation rather than by a regular system of stream and river drainage.

198. Such is a brief outline of the chief river-systems of the world—the Arctic, Atlantic, Pacific, and Indian. Though the basins of which they are composed have their own individual characteristics, there is still a great similarity, and

necessarily so, among the various members of a system. Thus the rivers of the Arctic system run more or less meridionally, flow from *warmer to colder* latitudes, and all their embouchures are for a larger portion of the year ice-locked and impervious to navigation. By the melting of the snows in their upper courses, they are flooded before the thaw has reached their lower waters, and thus the plains through which they pass are largely occupied by lakes and morasses. The rivers that descend the southern slopes of Asia, Europe, and North America, flow also in meridional courses, but pass, on the contrary, from *colder to warmer* latitudes, and consequently their embouchures are open at all seasons. Those of them that belong to the Atlantic system derive their floods chiefly from the melting of the snows along their upper courses; while the inundations of those belonging to the Indian system depend partly on the melting of the snows and partly on the periodical rainfalls in their lower courses. With the exception of the Rio del Norte and the Mississippi on the one hand, and the rivers that enter the Mediterranean on the other, all the basins of the Atlantic system, whether from the American, European, or African continents, run in latitudinal courses; and thus, from their sources to their embouchures, each passes along the same climatological zone. These and other great conditions must at once present themselves to the mind of the inquiring student, and produce the conviction that the idea of *river-systems* has something more to recommend it than the mere convenience of artificial arrangement.

199. Besides the oceanic systems there are what have been termed *Continental Systems*—a few inland basins cut off from all connection with the ocean, and having the equilibrium of their waters maintained by evaporation and absorption. The chief of these, as already mentioned, are the Aralo-Caspian basin in Asia; the Utah and Mexican in North America; the basin of the Andes plateau in South America; and in all likelihood, when better known, some similar depressions in Australia and Central Africa. On referring to the map, it will be seen that a number of the streams of central Asia—the Asiatic plateau—run inland to lakes, or lose themselves in the sand and shingle of the desert. This is the "Basin of Continental Streams" in Asia, and includes the Lob, Balkash, Helmund, and other

lake-hollows, with their tributary streams; the Aral, with its main feeders the Syr and Amoo; and the Caspian, with its rivers the Oural and Volga. Of these the most important is the Volga, which rises on the Valdai slopes at an elevation of 550 feet, and after a long and winding course of 2800 miles, during which it receives many important tributaries (the Kama, Viatka, &c.), falls by two main mouths into the Caspian Sea, which occupies an area of 140,000 square miles, is 82 feet below the level of the Euxine, and is calculated to undergo an amount of evaporation of 3 feet per annum to keep it at its existing level, which has not varied perceptibly since 1830. The Volga is the largest river in Europe, has a fall of only 633 feet during a course of 2400 miles, drains an estimated area of 397,640 square miles, and constitutes the great internal water-way of Russia. The seas and lakes of this basin, as indeed of all other continental basins, having no escape for their waters save by evaporation, must necessarily be more or less salt; hence the saline peculiarities of the Caspian, Aral, Balkash, Dead Sea, Lake of Utah, and others occurring in these so-called "basins of continental streams." Basins of this kind occur in comparatively rainless flats and plateaux; for were the amount of rainfall exceeding the evaporation, the sheets of water would accumulate till they overflowed their margins, and found an outlet towards the nearest oceanic area.

Lakes and Lacustrine Areas.

200. *Lake* is the general term for any considerable body of standing water surrounded by land, and not directly connected with the sea or any of its branches. Lakes are thus strictly terrestrial expanses, and belong to the land as much as the streams and rivers that channel its surface. Wherever there is a depression of that surface beneath the surrounding country or the bed of the nearest river, there water will accumulate (unless carried off by evaporation) till it rises above the lowest part of the enclosing margin and flows off by some river-channel. In this way we may have sheets of all sizes, from the merest pools to lakes occupying many thousands of square miles. Lakes owe

their origin to a variety of causes. Some, like the lakes of Central Africa, seem to lie in broad depressions of the earth's crust. Others, like those of many mountain regions, lie apparently in the deeper wrinkles formed during the compression and partial elevation of the rocks of the district. Some are formed by the local arrest of the natural valley drainage, by moraines, landslips, and the like. Others, like the *lagoons* of gently sloping shores, are merely shallow bays cut off from the sea waters by piled-up bars and sandbanks. A few, like the lakes of Central Italy, lie in the craters of extinct volcanoes. The basins of many, however, seem to have been excavated out of the solid rock, and as these occur in greatest abundance in high latitudes, they have been referred to the scooping action of the ice of the glacial period. Lakes generally consist of *fresh water;* but some, like the Caspian and Aral, having no river of discharge, are *salt*—while others, having only partial outlets, are *brackish.* They occur in all regions, but most abundantly on mountain table-lands and plateaux, and on the lower reaches of great plains, though some, like the Dead Sea, occur beneath the level of the ocean. Wherever there is a want of declivity, or any obstruction to the natural flow of the surface waters, there lakes will accumulate, and this in proportion to the extent of country, the magnitude of the obstruction, and the amount of rain and snow fall. In consequence of less evaporation, they occur also more abundantly in high than in low latitudes; and hence their frequency and magnitude in the northern regions of America, Europe, and Asia, as compared with other areas. It is usual to arrange lakes into *four* kinds: 1. Those that have neither outlet nor inlet—subterranean springs and rain supplying the water, and evaporation carrying off the excess. These are generally of small dimensions—lowland pools, mountain-tarns, and not unfrequently the craters of extinct volcanoes. 2. Those which have an outlet, but receive no running water, being fed by springs rising from their bottoms and rocky margins. Lakes of this class are also small, and for the most part situated in upland districts. 3. Those which, like the Caspian and Aral, receive streams of running water, but have no visible outlet—the balance of level being maintained by evaporation. Such lakes are more or less impregnated with saline matter; and this saltness must be still

on the increase. 4. Those that both receive and discharge streams of running water, and which form alike the most numerous and most extensive in both hemispheres.

201. To whatever class they belong, lakes form essential elements of diversity in the landscape, and perform important functions in the economy of nature. Exposing considerable surfaces to evaporation, they serve to temper the aridity of their respective districts, at the same time that they act as so many reservoirs, in which the superabundant supplies of winter are stored up for the increased requirements of summer. In many instances they act as checks to the too rapid discharge of rivers—retaining for perennial supply what would otherwise be run off in a few days, and restraining, moreover, the destructive flood, which is brought to rest in their placid areas. Occurring so frequently in the course of rivers, they act as settling-pools for the debris and sediment of their waters—the streams they discharge being pure and pellucid, whilst those they receive may be turbid and laden with impurities. In this way they get gradually silted up, and form rich alluvial tracts, the while that their outlet currents are deepening their channels and forming the means of a more efficient drainage. In this way lakes become important agents in the surface modification of the land; and one has only to cast his eye over the fertile dales and vales of long-settled regions, to perceive how much of these areas—now alluvial plains or *lake-lands*—must at some former period have been a mere succession of lakes and morasses. Biologically, too, these fresh-water sheets become the habitats of a peculiar flora and fauna—thus extending the range of Life, and affording conditions of existence that no other habitat could supply.

202. In Europe there are two main lake regions—a highland and a lowland; the former embracing the picturesque lakes of Britain, Switzerland, and Italy; the latter the numerous sheets that stud the Baltic provinces of Russia, Prussia, and Sweden. Spain and France are almost destitute of lacustrine areas. The highland lakes generally occupy the deep narrow troughs of mountain-glens, and from their situation and adjuncts are celebrated for their scenery; the lowland, on the other hand, spread over areas little depressed beneath the surrounding country, and are for the most part tame and unattractive. The waters of highland or Alpine

lakes are usually retained by rocky barriers, through which the outflowing stream is gradually deepening its channel, and thus their dimensions become less and less as the drainage outlet becomes deeper. On the contrary, the drainage of lowland sheets is often slow and sluggish; hence a large portion of their areas is little else than morass, which the accumulation of aquatic vegetation and sedimentary matter is year after year converting into alluvial land. With two or three exceptions (Platten See, Neusiedler See, &c.), the European lakes, strictly so called, consist of fresh water; they have all, or nearly all, streams of ingress and egress; vary in size from a few hundred square yards to several thousand square miles; rise slightly with the rains of winter and fall with the droughts of summer. The more notable of those in the northern lowland region are Lakes Ladoga 6330 square miles, Onega 3280, Saima 2000, Peipus 1250, and Enara 1200 square miles, in Russia; and Lakes Wener 2130, Wetter 840, and Maeler 760 square miles, in Sweden —the latter being only three or four feet above the level of the Baltic. The larger Alpine lakes are on the Swiss side: Geneva or Leman, 240 square miles, at an elevation of 1230 feet; Constance or the Boden See, 228 square miles, at an altitude of 1250 feet; Neufchatel, 114 square miles, and 1440 feet high; Lucerne, 98 square miles, and 1430 feet high; and Zurich, 74 square miles, at an elevation of 1330 feet; while on the Italian side there are Garda 182, Maggiore 150, and Como 66 square miles, at elevations respectively of 326, 680, and 685 feet. In the British Isles, Loughs Neagh, Corrib, Erne, and Loch Lomond, respectively 150, 63, 56, and 45 square miles in area, and 48, 31, 130, and 22 feet in elevation, are the largest, though others of smaller dimensions (Killarney, Westmoreland, and the Trossachs) are better known for their picturesque scenery and associations. Hitherto our lakes have been chiefly valued for their scenery; now that mining, agriculture, and manufactories are polluting our streams, they are becoming important reservoirs for many of our towns—their waters being carried by gravitation often to great distances, and yielding a copious and wholesome supply.

203. In Asia, the lakes occupy three main and distinctive regions—the mountains and plateaux of the central highlands, the alluvial lowlands of China and Siberia, and the

depressed areas of the Aralo-Caspian and Dead Sea. Unlike those of Europe, many of the Asiatic lakes are salt or brackish, and this peculiarity belongs more especially to those having no river of outlet. Respecting these salt or brackish sheets, accounts differ considerably as to the amount of saline matter held in solution in their waters—a difference that may arise either from taking the specimens at different places (some being drinkable at one end and brackish at the other), at different seasons of the year, or from errors in analysis. Whatever the source of error, there can be no doubt that where new saline supplies are continually carried in by rivers and springs, and none carried off by running water, the percentage must be gradually on the increase. Of the *saline* lakes, the more important and better known are the Caspian (slightly fresher than the ocean), 82 feet beneath the level of the Black Sea, having an area of 130,000 square miles, and an extreme depth of 960 feet; the Aral, 36 feet above sea-level, and having an area of 26,000 square miles; Balkash or Tengiz, having an area of 7000 square miles; Urumiah (25 per cent of salts), 1800; Van, 1600; Zurrah, 1600; Tongri-nor (*nor*, lake), 1800; Koko-nor, 1500, at an elevation of 10,500 feet, salt and undrinkable, and of an exquisite blue colour; Lop, 1300; and the Dead Sea, 360 square miles, with a surface depression of 1312 feet beneath the level of the Mediterranean, an extreme depth of 1300 feet, and containing from 25 to 26 per cent of saline ingredients. Of the *fresh-water* sheets the largest is Baikal (the "Holy Sea" of the Russians) in Siberian Tartary, with an area of 14,800 square miles, at an altitude of 1363 feet, and now plied on by small steamers; and Tong-Ting, Poo-yang, and Tai-hou in China, having respectively areas of 2000, 800, and 700 square miles, and all valuable aids to the internal communication, commerce, and agriculture of that peculiar country. Besides these may also be noted Zai-zan in Mongolia, 1000 square miles; Bookanor in Tibet, 1000; Erivan in Armenia, 500; and Tiberias in Syria, 76 square miles, at a depression of 328 feet beneath the Mediterranean.

204. In Africa there are several lakes less or more known to geographers; but while the internal configuration of that continent remains undetermined, it is impossible to arrange them into anything like systems or areas. Between the

Atlas range and the Sahara, and fed by streams from the former, there exists a series of minor lakes, of which the largest (Loudeah, &c.) lies in Tunis; in the hilly region of Nigritia the existence of sheets of considerable magnitude (Tchad, Dibbie, Fittie, &c.) has been so far determined; in the equatorial region, Victoria, 21,500 square miles, and 4168 feet above the level of the sea; Albert, of unknown area, and 2720 feet above the sea; and several other reservoirs of the Nile: and in the southern table-land, many apparently fluctuating sheets; Tanganyika, 9240 square miles, 2756 feet above the sea, and of unknown depth; Bangweolo, 150 miles long; Nyassa, 9000 square miles in area, and 1500 feet above the sea, &c. The last three, from the western flow of their effluent rivers, and as has been proved by Stanley, form the sources of the Livingstone and Congo. Indeed, as has been shown by Livingstone, Stanley, Cameron, and other explorers, the heart of Africa, instead of being a thirsty and arid table-land, is a well-watered plain, or series of plains, often densely wooded, and abounding in products (mineral, vegetable, and animal) unrivalled by any other tropical region. Among the longer known lakes may be mentioned Dembea or Tzana in Abyssinia, at an elevation of 6270 feet, and embracing an area of 1400 square miles; the deltic areas of Menzaleh and Mareotis in Egypt; and the salt-water lake of Assal in Abyssinia, extending to 30 square miles, and lying in a depression 570 feet beneath the level of the Red Sea.

205. With regard to Australia, we know that certain areas covered with water during the rains are but marshes or mud-pools during the season of drought, and that, along many portions of the sandy coasts, there exist saline and brackish lagoons; but we are yet too slenderly acquainted with the interior to speak with certainty as to the existence of *lakes* in the true sense of the term, either fresh-water or saline. So far as we have learned from exploring parties, the chances are against the existence of perennial lakes, though numerous creeks and temporary pools are scattered, at distant intervals, over the continent.

206. In South America there are comparatively few lakes, and these, for reference' sake, may be arranged into three distinctive regions,—namely, the mountain-glens and depressions of the higher Andes; the low plains that

border the eastern flanks of the Andes; and the still lower river-plains that trend toward the Atlantic. Of the Andean lakes the most remarkable is Titicaca, situated at an elevation of 12,847 feet, embracing an area of 3800 square miles, and stamping peculiar features on the scenery, life, and civilisation of the surrounding district. It is fed by several streams from the Andes, but discharges itself by a single outlet, the Desaguadero, which after a short course disappears, partly by evaporation and partly by absorption, into the sandy and arid soil through which it flows. Of the lakes that skirt the Andes on the east, many of them are of temporary nature, being extensive sheets during the rains, but mere marshes and salt pools (*salinas*) during the period of drought. In the lower plains of the Plata, Amazon, and Orinoco there exist many creeks, lagoons, and stagnant areas that appear in the dry season as pools and lakes, but during the rains as one vast area of inundation.

207. In North America the lakes may be said to affect only two main districts—a highland and a lowland; the former the troughs and depressions of the Rocky Mountains from Panama on the south to Columbia on the north, and the latter the northern section of the great central plain from the southern boundaries of Canada to the Arctic Ocean. In the former area the more important sheets are Nicaragua, 3500 square miles, at an elevation of 128 feet; Maragua, 450 square miles; and Yojoa, 150 square miles, in Central America: Chapala in Mexico, 1000 square miles: and in the United States, Utah, 150 square miles (28 per cent of salts); and the Great Salt Lake, 1800 square miles, at an elevation of 4200 feet. Of the lowland section the more important are the great "fresh-water seas" that form the lacustrine chain of the St Lawrence, and which, from their size and depth, influence alike the climate and commerce of the country. These are Superior, with an area of 32,000 square miles, an altitude of 628 feet, and a depth of 900 feet; Michigan, 24,000 square miles, altitude 574 feet, and depth 1000 feet; Huron, 20,000 square miles, altitude 574 feet, and depth 1000 feet; Erie, 9600 square miles, altitude 565 feet, and depth 84 feet; and Ontario, 6300 square miles, altitude 232 feet, and depth 500 feet. Besides these, there is the immense

lacustrine network of the extreme north, forming with that of Canada a lake-region unsurpassed by any other on the globe. Of the largest of these boreal, shallow, marshy, and long-frozen lakes, we may enumerate Great Bear, 19,000 square miles; Great Slave, 12,000; Winnipeg, 9000; Winnipegoos, 3000; Athabasca, 3000; Deer, 2400; Manitoba, 2100; Wollaston, 1900; and Lake of the Woods, 1200 square miles,—the presence of which tends to render the region more rigorous in climate, and all but impassable even to the hunter and fur-trader. Many of these are gradually silting up, however, and in course of time will become alluvial plains, like the prairies, much of which may have had a similar origin in earlier geological ages.

RECAPITULATION.

208. In the preceding chapter attention has been directed to what may be termed the *terrestrial* waters of the globe—that is, to the springs, streams, rivers, and lakes that occur on the land, in contradistinction to the great united mass which constitutes the Ocean. Though separable in this way, it is still the same vast volume of waters we have to deal with, its appearance on the land being only local and temporary. The vapour exhaled from the ocean is conveyed to the land, where, condensed into rains and snows, it falls and forms springs and streams, and these by their union give birth to rivers and lakes. But the stream and river are ever hurrying to the ocean again—again to be evaporated as *fresh water*, again to fall as rain and snow, and again to course the dry land, and to carry with them a portion of those ingredients which, accumulating within certain limits, originate the peculiar *saltness* of the ocean. The rain and snow that percolate the rocky crust reappear at the surface as *springs*, which, according to their situation, may be superficial or deep-seated; according to their supply, temporary, intermittent, or perennial; according to their temperature, cold or thermal; and according to the rocky material

through which they pass, either pure or mineral—that is, impregnated less or more with saline, calcareous, siliceous, chalybeate, and other mineral and metallic substances.

209. By their union, springs and surface runnels form *streams*, and these streams occurring most abundantly in hilly regions, unite one with another as they descend to the plains, and there ultimately form *rivers*, whose continually augmented volumes constitute one of the most important features in the hydrography of the globe. The highest or most important spring to which we can trace a river constitutes its *source* or *rise*; and from this source, through all its windings till it finally falls into the sea by one or by many mouths, lies its *course*. It is usual to divide river-courses into upper, middle, and lower stages—the upper being characterised by ravines and waterfalls, the middle by rapids and cataracts, and the lower by a broad gentle current which often finds its way into the ocean by several branches through a low-lying and marshy *delta*. The track worn or hollowed out by running water constitutes its *channel*, and the land that forms the margins of this channel is known as its *banks*—that on the right hand as we descend the current being termed the right bank, the left hand the left. The streams that enter any river or main current from either side form its affluents or tributaries, and the entire expanse of country drained by a river and its tributaries is said to be the *basin* of that river. An ideal line connecting the ultimate sources of all the tributaries of a river, forms the *boundary* of its basin; and generally speaking, the ridge from which the streams of a country flow in opposite directions is the *watershed* of that region.

210. As all the streams of a river-basin fall to the lower level of that basin, so several river-basins may descend to the still broader basin of some sea or ocean, and all such basins discharging themselves into the same sea constitute a *river-system*. The river-systems are naturally connected with the great oceans into which they flow; and thus we

have the Arctic, the Atlantic, Pacific, and Indian systems, together with a few inland systems whose streams flow towards certain depressed areas altogether cut off from connection with the ocean. These are the Aralo-Caspian basin, the Utah, the Mexican, the Bolivian, &c., whose waters flow inwards to certain lakes, and are thence carried off by evaporation. Where the slopes of a country are pretty uniform, the surface waters are at once carried off by streams and rivers; but where any unusual depression occurs, there they accumulate and form *lakes* and *morasses*. Most of these lakes both receive and discharge running water; but some of a small size, being fed by springs and reduced by evaporation, neither receive nor discharge running water; while others, again, receive streams and rivers, but have no outlet—their surplus waters being carried off by evaporation. The first set of lakes are always fresh; the last, like the Caspian, Aral, and Dead Sea, always less or more brackish and saline.

XI.

THE ATMOSPHERE—CLIMATOLOGY.

Nature and Constitution of the Atmosphere.

211. HAVING, in the preceding chapters, directed attention to the leading features of the Land and Water—the mountains, table-lands, and plains of the one, and the seas, lakes, and rivers of the other—we now proceed to consider the main relations of the Atmosphere or aerial envelope (Gr. *atmos*, vapour, and *sphaira*, a sphere) by which the whole is surrounded. What is the nature and composition of this envelope, what its capacity for heat and moisture, what are the motions to which, as an elastic fluid, it is subjected, and generally, what are its conditions as the great medium of climate (heat, cold, winds, rains, &c.) on which the Life of the globe is so intimately dependent? This varied subject of climatology belongs more especially to the science of Meteorology; but as an integral portion of the globe, and bearing on everything—organic and inorganic—that presents itself at the surface, the atmosphere and its principal phenomena become important themes to the student of Physical Geography.

212. As already stated in paragraph 23, the atmosphere surrounding the globe, and partaking in all its motions of revolution and rotation, is an aeriform fluid consisting of nitrogen and oxygen gases—79 parts of the former to 21 of the latter by volume, or 77 to 23 by weight, together with a small and variable percentage (averaging .04, but ranging from .02 to .10) of carbonic acid gas, and, occasionally, of local and temporary impurities. These gases are merely

in a state of admixture or diffusion, as is also the invisible vapour which less or more is ever present in the atmosphere. This special composition is alike indispensable to vegetable and animal life. Both animals and plants breathe, if we may so speak, the air; but while animals absorb oxygen and emit carbonic acid, plants decompose carbonic acid, retaining the carbon and setting free the oxygen. By this means the balance of composition is harmoniously maintained, any local variations being too unimportant to affect the general result. Being an elastic or compressible medium, the air nearest the sea-level, pressed upon by all the superincumbent mass, is denser than that at considerable elevations; and by calculating the rate at which this density decreases, it is estimated that, at the height of 45 or 50 miles, the atmosphere becomes so rare or attenuated as to be all but inappreciable—and yet *not inappreciable*, for meteors in their passage through it become ignited at elevations of 90 and 100 miles. What the *absolute* height or extension may be is still an undetermined problem—200 miles, 212 miles, and even greater altitudes being given, according to the principles on which the calculations are founded.

213. The mean pressure of the atmosphere taken at the sea-level is usually reckoned at 14¾ lb. avoirdupois (14.7304 lb.) upon the square inch—a pressure which, being equal on all sides, is insensible to living beings, the only inconvenience being experienced at great altitudes (5 or 6 miles), where the air becomes too rare and light to maintain respiration, or to retain sufficient heat for the functions of vitality. This aerial pressure is balanced by a column of mercury 30 inches in height, and by a column of water 34 feet in height; hence the construction of the *barometer*, and hence also the term *barometric pressure* as applied to the oscillations of the atmosphere, which sometimes rise above and at other times fall below this normal standard. The pressure or weight diminishing as we ascend, the barometric column will fall in proportion, and this fall (correction being made for varying effects of temperature) becomes a convenient measure of altitude. Thus, at the sea-level, near the foot of Chimborazo, Humboldt found that the barometer stood exactly at 30 inches; while at the elevation of 19,332 feet, to which he ascended, it fell to 14⅔ inches. Again, under the normal pressure of the atmosphere, water at the level of the

sea boils at the temperature of 212° Fahr.; but as the pressure becomes less, ebullition takes place sooner, and thus, as we ascend, the boiling-point diminishes, and may in like manner be taken as a measure of altitude—1° of diminution being equivalent to 590 feet of ascent or thereby. Of course, water at 212° and water at 190° (the boiling-point at 13,000 feet in the Andes) will produce very different effects—absolute temperature, and not mere ebullition or bubbling-up under diminished pressure, being the true test of its heat.

214. As a general rule, the temperature of the air decreases in proportion as we ascend above the ordinary surface of the earth. One of the chief causes of this is the circumstance that only a very small fraction of the sun's heat is arrested in its progress through the atmosphere, the greater part reaching to, and heating the surface of the earth. The lowest strata of the air in contact with that heated surface are consequently the warmest, while the highest strata, being farthest removed from it, are the coldest. As a property of the gaseous or aeriform nature of the atmosphere, the vapour or minute watery vesicles generated from the earth's waters by the heat of the sun, ascend and are diffused through its mass in an invisible state. *The humidity of the atmosphere decreases with the height,* and this in so rapid a ratio that at the altitude of 5 or 6 miles it is all but inappreciable. The vapour, invisible at first, becomes visible on being condensed by colder currents; hence arise fogs, mists, rains, snows, and other kindred phenomena. The large amount of watery vapour in the atmosphere acts as a cloak to prevent the free radiation of the heat of its lower strata; while its higher strata being almost wholly devoid of moisture, have nothing to prevent them from giving off what little heat they naturally receive from below into the intensely cold regions of outer space. The effective portion of the atmosphere, so far as its heat and moisture are concerned, lies therefore within a few thousand feet of the earth's surface, all above the limit of 5 or 6 miles being inoperative or nearly so in the production and regulation of climate. Like all gaseous bodies, air is expanded by heat and contracted by cold. In every region, therefore, where the surface of the earth is abnormally heated by the sun's rays, the air in contact with the ground

expands, becomes lighter, and ascends into the higher parts of the atmosphere, the colder and denser air from the surrounding regions rushing in from all sides to supply its place. Again, the addition of watery vapour to the air lessens its density, and this in proportion to the temperature ; so that in areas of excessive evaporation a similar ascending current is originated, and the heavier air of the colder regions flows in to fill up the vacancy. In both these ways currents or *winds* are generated in the atmosphere, and on these currents depend in great measure the essentials of climatic diversity.

215. Had the globe presented either one uniform surface of land or one uniform surface of water to the sun's rays, the interchanges of heat and moisture between the colder and warmer, the drier and moister regions of the atmosphere, would have been regular and continuous. But the earth's surface being composed of land and water in unequal proportions, and this land lying not only in irregular masses but presenting also irregular surfaces of highland and lowland, the movements of the atmosphere are so broken up and complicated that the winds and rains, the heat and cold, are rendered extremely variable—so variable, indeed, that Meteorology consists as yet more of collections of facts and approximations to results than of ascertained and definable laws. Under these circumstances we shall glance merely at the leading features of the atmosphere—its heat, moisture, and motions—as bearing more directly on the *climate*, or weather-conditions, if we may so express it, of the earth's various regions.

Its Heat and Moisture.

216. In dealing with the subject of climate, the superficial or atmospheric temperature of the globe may be viewed as wholly dependent on the heat of the sun—the amount conveyed from within (par. 20), or radiated from the moon and other external sources, being by far too feeble to have any perceptible influence. As is well known, the solar rays exercise the greatest effect within the tropics, where they fall vertically or nearly so on the earth's surface, and this effect gradually declines as we proceed through the

temperate zones towards either pole. In other words, the higher the angle at which the sun's rays strike the earth the greater their heating power, and the lower the angle the less the amount of heat imparted. We feel the truth of this every summer day, when the sun is high above during the scorching noontide, and when his beams fall at a lower angle during the cooler afternoon. And the causes of these differences are evident at a glance. When the sun's rays are vertical, as at A (see fig.), the amount of heat represented by the angle A B C is all concentrated upon the small space

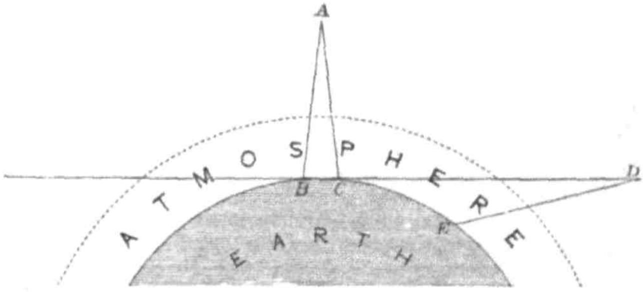


Figure showing the influence of the varying inclination of the sun's rays.

B C of the earth's surface. When the sun has declined to D, the same amount is necessarily spread out over the much larger space B E, each single spot receiving a very much smaller proportion than before. Again, at A, the sun's rays pass through a comparatively thin film of moisture-laden atmosphere, and but little of their heat is arrested by it. At D, on the other hand, the thickness of the atmosphere through which the rays have to pass is immensely increased; much more heat is absorbed, and the quantity remaining to heat the surface of the earth at any single locality in the space B E is proportionally diminished. In this way it has been calculated that the portion of the earth's surface lying between 23° 44′ 40″ on either side of the equator forms a belt within which the solar heat received is equal to what is received by all the rest of the world; and hence the learner will perceive the applicability of the terms "torrid," "temperate," and "frigid" zones. Keeping out of view all minor modifications produced by the peculiar disposition

of sea and land, as well as by the sun's alternate passage to the northern and southern hemisphere along the course of the ecliptic, it may be received as the first great axiom, that the superficial temperature of the globe is highest under the vertical incidence of the sun's rays near the equator; and that it gradually becomes lower and lower as we proceed towards either pole, and this in proportion to the obliquity at which the heat-giving rays fall upon the surface.

217. As we have already indicated, there is a gradual decrease in the temperature of the air as we ascend from the level of the sea to higher elevations. The rate at which this diminution takes place depends, as has been shown by Mr Glaisher's balloon experiments in 1863, on many correlative circumstances—dryness, moisture, currents, &c.; but, as a general fact, the decrease goes on as we ascend—and, from Professor Wahl's experiments, apparently more rapidly in the upper than in the lower strata of the atmosphere. The old rule of a *regular* decrease of 1° Fahr. for every 300 feet of ascent must therefore be abandoned, and the following generalisation be adopted—viz., that there is a decrease, but a *variable* one, for every 100 feet of ascent during the day up to 2000 feet, and a small but also variable increase up to the same height during the night, when radiation from the earth begins, and the heat is arrested by the vapours in the atmosphere. In this way—that is, by a general diminution of the temperature as we ascend—the lower plains of a region may be teeming with vegetation, while the higher mountains are enveloped in perpetual snow. We have thus two great causes affecting the superficial temperature of the globe—distance from the equator, and elevation above the level of the sea; so that at any given latitude it is much the same whether we travel towards the nearer pole or ascend a lofty mountain. In both we will meet with a gradually decreasing temperature, in both we will meet with a similar change in animal and vegetable life, and in both we will ultimately reach a limit of perpetual ice and snow. In the case of elevation, this limit is known as the *snow-line*, at which the air in summer attains the temperature of freezing water; and though slightly modified by surrounding circumstances, it varies primarily with the latitude—ascending from 2000 feet within the polar circle to 15,000 or 16,000 feet in the vicinity of

the equator. In the case of horizontal extension, *the line of constantly frozen ground* differs in either hemisphere,—that in the northern (see Map of Isotherms, p. 230) assuming an irregular course, in consequence of the unequal distribution of sea and land, the variation in local temperature caused by currents, prevalent winds, and the like—and that of the southern being less determinable, in consequence of the greater expanse of Antarctic Ocean.

218. Another cause of variation in atmospheric temperature is the difference in the manner of reception and radiation of the sun's heat by the respective surfaces of land and water. The heat falling on the land is partly absorbed and conducted downwards into the soil, and partly radiated into the atmosphere. The amount absorbed will differ according to the colour, slope, and character of the land (dry, firm, and dark-coloured soils being most favourable for absorption); and according also as it is naked or shut out from the sun's rays by a covering of vegetation. The amount radiated differs with almost every passing condition of the atmosphere—radiation going rapidly forward under a still, clear sky, while a cloudy atmosphere, or even a passing mist, serves to retard it. The greater quantity of heat absorbed by day is given off by night; and the amount accumulated during summer is returned to the atmosphere during winter. The depth thus affected by summer's heat or winter's cold will differ according to latitude, soil, and situation; but, on the whole, it may be safely asserted that beyond 60 or 80 feet the temperature of the earth's crust is altogether unaffected by external influence. Indeed, for all practical purposes the superficial temperature of the land, as affecting climate, may be regarded as confined to a very few feet beneath the surface—the slow conducting power of the soil and capillary attraction of moisture from below combining to limit its downward tendency.

219. On the other hand, the heat that falls on the water penetrates to a considerable depth, is diffused by waves and currents, and accumulates within the upper waters of the ocean. The heat that falls on any zone of the land is absorbed and radiated wholly within that zone; whereas that falling on any zone of the ocean is diffused and interchanged between all the surrounding zones. As the specific heat of the ocean is much greater than that of the land,

while it exposes more than thrice the surface to the sun's rays, it becomes, as it were, a great storehouse of heat for the exigencies of the land. It is for this reason that islands and seaboards possess a milder and more equable climate than the interior of continents—being warmer during winter and cooler during summer. The British Isles, with their comparatively cool summers and mild variable winters, are thus said to possess an *insular climate;* while the interior of Germany, with its excessively hot summers and cold winters, is said, on the contrary, to possess a *continental climate.* In tropical latitudes, unaffected, of course, by winter, the interior of continents is always much warmer than the sea-coasts and adjacent islands. It is also for this reason that the northern and southern hemispheres, having unequal distributions of sea and land, are differently affected in their zones of climate—the greater extent of land in the northern imparting to it, as it were, a continental climate; while the greater expanse of ocean in the southern confers on its similar latitudes more of an insular climate. It is, further, to this unequal specific heat of land and water that we owe the phenomena of sea and land breezes. During day the atmosphere immediately above the land is heated up to a far higher temperature by terrestrial radiation than that above the ocean, hence the cooler sea-breeze sets in towards the land to restore the balance; while during the absence of the sun the more rapidly cooled land-atmosphere sets out as a land-breeze towards the more slowly cooling surface of the ocean. In fine, it is mainly owing to the unequal distribution of sea and land, and to the different modes in which the two elements are affected by the sun's heat, that we owe the great essentials of climatic diversity—the air and ocean currents, the vapours and rains of one region, varying from the winds, currents, and moisture of another.

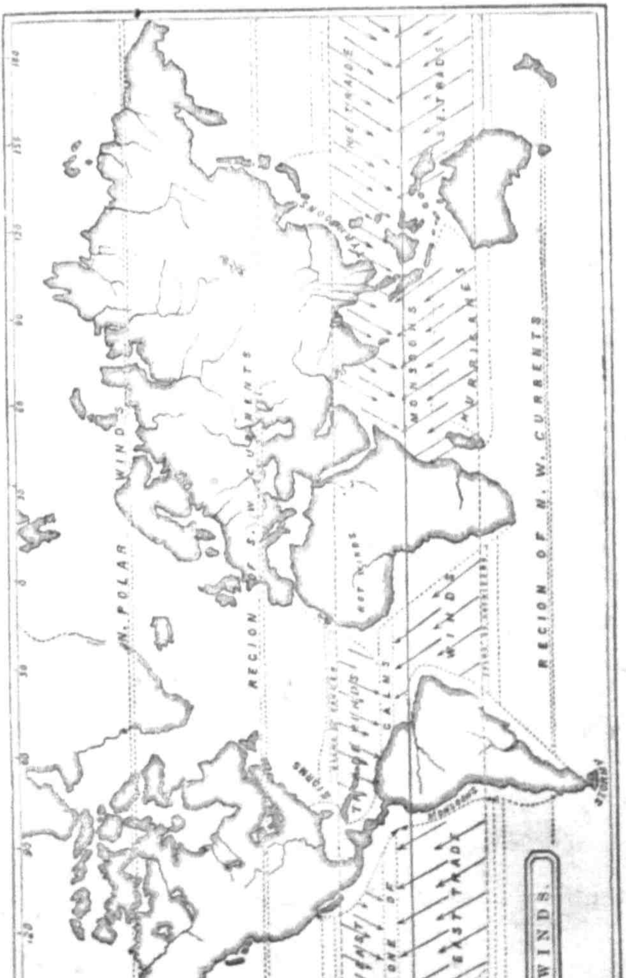
220. Whatever the temperature of the air, it is incessantly receiving *moisture* from the surface of the land and water. This vapour arises and is diffused through its mass in an invisible form, and becomes visible only when condensed into mists, fogs, rains, and snows. It arises alike from land and water, but most copiously and persistently, of course, from the surface of the water. The superficial moisture of the land, unless where clothed with vegetation, is rapidly con-

verted into vapour; but the supply from this source is irregular and limited compared with that derived from the water. Surface for surface, salt water is less vaporisable than fresh; hence a slight check to evaporation from the vast and extended surface of the ocean. It rises from rivers, lakes, and seas in every latitude, but most abundantly, of course, within the tropics, where the sun's heat is the greatest. So great is the evaporation within that zone, that it has been estimated as annually sufficient to reduce the surface of the sea to a depth of 12 or 16 feet—a waste, of course, that is incessantly counterbalanced by influx from other latitudes. The warmer the air the greater its capacity for moisture. When the air contains as much vapour as it can retain in the gaseous state, it is said to be saturated. Any decrease in the temperature of air in this condition reduces its point of saturation; the moisture in excess is at once condensed, and becomes visible in the form of mists, fogs, dew, or rain.

221. As in the case of other meteorological phenomena, the circumstances connected with the production and retention of atmospheric vapour are extremely complicated: but in general terms it may be stated that heat is the grand promoter of evaporation; that a gentle current of air, by removing the vapour as it is formed, is more favourable than a stagnant atmosphere; that it is retarded by moist and cloudy conditions of the air, even though the sensation of heat be considerable; and that its amount is greatest between March and November, and least between November and March. Vapour, like glass, allows the solar heat to pass through; but non-luminous heat, and therefore the non-luminous heat radiated by the earth, is conserved or kept in by the vapour surrounding the earth. "No doubt," says Professor Tyndall, "can exist of the extraordinary opacity of this substance to the rays of obscure heat; particularly such rays as are emitted from the earth after being warmed by the sun. Aqueous vapour is a blanket more necessary to the vegetable life of England than clothing is to man. Remove for a single summer night the aqueous vapour from the air which overspreads this country, and you will assuredly destroy every plant capable of being destroyed by a freezing atmosphere. The warmth of our fields and gardens would pass itself unrequited into space, and the sun

their influence on the trade or commerce of the world), which, within the torrid zone and a few degrees beyond it on either side, are ever sweeping round the globe in a westerly direction. This is occasioned by the fact that the region near the equator is most intensely heated—the other zones becoming colder and colder towards either pole. Under these circumstances the air of the torrid zone becomes rarefied and ascends, while the colder and denser air sets in from either side to supply the deficiency. There are thus generated two great sets of currents—colder under currents setting in towards the equator respectively from the north and south, and warm upper-currents flowing off from the equator towards either pole. If, then, the atmosphere were subject to no other influence than temperature, a *north wind* would always prevail along the earth's surface in the *northern hemisphere*, and a *south wind* in the *southern hemisphere*. But as the polar currents proceed towards the equator, they gradually come into zones having a greater velocity of movement to the eastward, owing to the earth's rotation, than the winds themselves naturally possess; and thus they lag behind, as it were, apparently moving in a somewhat westerly direction (as exhibited in the accompanying Sketch-map), so as to become *north-east* winds in the northern hemisphere, and *south-east* winds in the southern.

225. In the Pacific, the north-east trade-wind may be said to prevail between the 25th and 2d degrees of N. latitude; while the south-east trade ranges more widely between the 10th and 21st of S. latitude. In the Atlantic, on the other hand, the former is comprised between the 30th and 8th degree of N. latitude, and the latter, within the 3d of N. and the 28th of S. latitude. These limits, however, are not altogether stationary, but depend on the seasons—advancing towards the north during the summer of the northern hemisphere, and receding to the south as the sun withdraws to the southern tropic. Within these somewhat fluctuating zones (which may be estimated at 1000 miles in diameter), the trade-winds are steady and perennial, travelling at the rate of from ten to twenty miles an hour, and wafting onwards in safety the merchandise of the globe. As they approach the continents, their courses become interrupted in consequence of the unequal heating of the land and water surfaces; hence within these coast-areas


WINDS.
N. POLAR WINDS
REGION OF S. W. CURRENTS
REGION OF N. W. CURRENTS
MONSOONS
HURRICANES
NORTH EAST TRADE
ZONE OF CALMS
SOUTH EAST TRADE

they assume the character of periodical rather than of constant currents, being deflected at certain seasons from their normal directions.

226. As the north-east and south-east trades approach the equator of temperature, their currents begin to fail, and this effect, augmented by the upward tendency of the highly heated air of that region, produces a zone or belt of calms, which fluctuates a few degrees north and south, according to the seasons. If the approaching trades be equally reduced in any locality, a dead calm will be the result; but as this is seldom the case, the zone is also characterised by short gusty winds, which vary in force and direction according as either main current prevails. This *zone of calms and variables*, as it is termed, is further characterised by the frequency and intensity of its thunderstorms —the crossing and collision of currents of unequal densities being favourable to the manifestation of electrical phenomena. In the Atlantic, the region of calms (see Sketch-map) ranges in August between 3° and 12° N. lat.; but in February it extends from 1° 15′ to 6° N. lat. A portion of the zone near the Cape Verde Isles is known to sailors as "the rainy sea;" and is described as "a region doomed to continual calms, broken up only by terrific storms of thunder and lightning, accompanied by torrents of rain. A suffocating heat prevails, and the torpid atmosphere is disturbed at intervals by short and sudden gusts, of little extent and power, which blow from every quarter of the heavens in the space of an hour—each dying away ere it is succeeded by another. In these latitudes vessels are sometimes detained for weeks." In the Pacific, the region of calms is comprised within the 2d degree of north and south latitude, near Cape Francis and the Galapagos Islands—a narrow belt (300 miles or thereby) separating the two trades, and characterised by the same phenomena as the calm zone of the Atlantic.

227. Besides the trade-winds, which are the most persistent of all aerial currents, there are certain winds in the higher latitudes that also blow with considerable continuity. The heated air which ascends from the tropics, and flows off towards either pole, gradually descends as it proceeds; but as it passes from latitudes having a high to others having a low rotatory velocity, its speed outstrips theirs, and the

wind appears to come from the west. In this way the prevailing winds in the higher latitudes of the northern hemisphere are from the *south-west*, and those in the southern hemisphere from the *north-west;* and though many causes —unequal distribution of sea and land, position of continents, irregularity of land-surface, &c.—tend to disturb this continuity, and thus to reduce all except the trades to the category of variable winds next to be described, still, on the whole, there is a marked predominance of westerly winds. In our own islands, the fact must be sufficiently obvious to every observer; in the North Atlantic, the average packet-voyage from New York to Liverpool is 23 days, while the return voyage requires 40 days; and in the vicinity of Cape Horn, westerly winds are three times more frequent than those from an easterly direction.

228. Among the constant currents of the atmosphere must also be enumerated the *north* and *south polar winds*, which, as mentioned in the theory of the trade-winds, are continually flowing north and south from either pole. And further, as an under current almost invariably implies the existence of an upper current in a contrary direction, we may notice also the *upper west wind of the tropics*, which, high above the trades, seems constantly flowing in an opposite direction. Proofs of these upper tropical winds, or *anti-trades*, as they are sometimes termed, are found in the circumstance that dust ejected from the volcanoes of the West Indies has fallen on ship-deck several hundred miles to the eastward; and also in the often-observed fact, that a similar wind prevails near the summit of Teneriffe (12,000 feet), while the regular trade-wind is blowing from an opposite direction below.

Periodical Winds—The Monsoons, &c.

229. As all winds have their origin in the unequal distribution of atmospheric pressure, due primarily to the disturbing action of the unequal temperatures of different parts of the earth's surface, it follows of necessity that in those regions where the land or water is periodically heated and periodically cooled, there we shall find *periodical* winds. Where the local distribution of heat depends upon variable or intermittent cause, there the winds will be *variable* and intermittent.

Of the *periodical winds* the most important are the MONSOONS (from the Malay word *moussin*, signifying seasons), which in certain countries within and near the tropics blow from a certain quarter for one-half the year, and from an opposite point during the other half—the period of change being marked by calms, tempests, and variables. In other words, the monsoons are but the trade-winds interrupted in their regular action by the geographical peculiarities of the regions in which they occur. From April to October the *south-west* monsoon prevails north of the equator, and to the *south-east* in the southern hemisphere; but from October to April the *north-west* monsoon blows south of the equator, and the *north-east* in the northern hemisphere. Of course, the farther from the equator the later in the season will the south-west and north-west monsoons occur; and thus it happens that in India, at Anjengo, on the Malabar coast, 8° 30′ N. lat., the south-west monsoon commences as early as the 8th of April; at Bombay, 10° N. lat., about the 15th of May; in Arabia it commences a month earlier than on the coast of Africa; and in the northern part of Ceylon, fifteen or twenty days earlier than on the coast of Coromandel.

230. The cause of the monsoons is to be sought in the effect produced by the sun during his apparent annual progress from one tropic to the other. In summer the great elevated expanse of land in Central Asia becomes excessively heated under the rays of an almost vertical sun. The air above expands, and a region of low atmospheric pressure is formed, into which the colder and denser air from the surrounding areas flows in a spiral form, moving in a south-west direction across India and China from the Indian Ocean. In winter we have exactly the reverse of this. The high and dry table-lands of Central Asia become excessively cooled, the air above is condensed and flows outwards in a spiral form (see par. 235) upon the warmer areas around, blowing across north-east Siberia from the north-west, across China from the north, and across India from the north-east. Similar periodic winds or monsoons, due to corresponding causes, occur in other regions; but none are so well marked as those of the Indian Ocean. The winds of Australia blow landwards in the hot months, and seawards in the cold season. Off Mozambique the trades change to the east

during summer; and the south-east trade-wind of the Atlantic is changed into a south-west monsoon on the Guinea coast, and a north-west monsoon off Brazil.

231. Equally remarkable for their persistency, though local in their areas and limited in their times, are the *land* and *sea breezes* which occur on almost every seaboard, but most notably, of course, within the tropics. During day the land-surface, from its low conducting power, acquires a more elevated temperature than the adjacent waters; and the air above it, partaking of this heat, becomes rarefied and ascends, while the cooler and denser air from the ocean sets in as a *sea-breeze*, to restore the equilibrium. This sea-breeze, especially in tropical latitudes, commences about nine in the morning, gradually increases in force till the middle of the day, and falls away as the sun declines in the afternoon. As evening approaches, the air over the surface of the land becomes more rapidly cooled by radiation than that over the water, and then a cool *land-breeze* sets out towards the ocean, blows freshly during the night, and dies away towards morning, when the sea-breeze again commences. The extent of these breezes is exceedingly variable. In some localities they blow only for a few miles out and in of the shore-line, while in others their bracing and refreshing influence is experienced for many leagues in either direction.

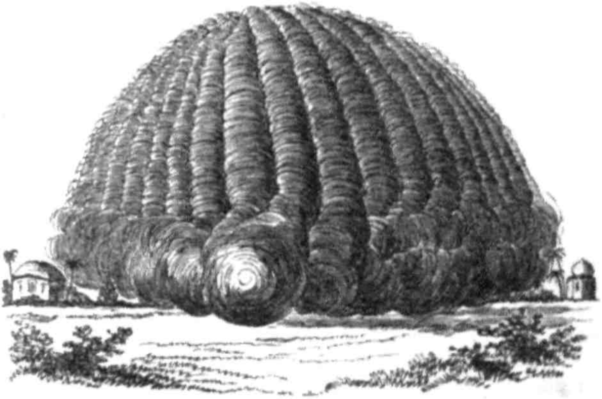
Variable Winds.

232. Owing to the mobility of the atmosphere, and the many causes that may temporarily affect its temperature and density, the *variable winds* are exceedingly numerous and capricious—so capricious, that "fickle as the wind" has become an established simile in every extra-tropical country. We say *extra-tropical*, for within the tropics the trades and monsoons are the prevalent winds, and these, as we have seen, maintain a remarkable degree of permanency and periodicity. But in extra-tropical regions, where the force of the permanent winds becomes feeble, a thousand causes (as unequal distribution of land and water, nature of soil, irregularity of surface, &c.) occur to disturb these currents, and thus almost every district has its temporary winds, varying in direction, force, and duration. Fickle and uncer-

tain as they may appear, they are, nevertheless, the results of law and law-directed forces. They all have their origin in local differences of atmospheric pressure—the wind blowing from a region where there is a surplus to one where there is a deficiency of air, and entering upon it in the spiral manner due in part to its own impetus and in part to the rotation of the earth. This will be noticed more fully under the heading of Storms (235).

233. Generally speaking, in the higher latitudes of the northern hemisphere, a south wind is warm and moist, because it comes from warmer regions, and passes over a greater extent of ocean; while, on the contrary, and for opposite reasons, a north wind is cold and dry. It is for this reason that the westerly and south-westerly winds of Europe are humid and genial, and the north and north-easterly hard and ungenial. These major currents are of course much modified in their passage over certain localities; hence the various characteristics assigned to the *Etesian winds* (Gr. *etesios*, annual) that prevail very much in early summer all over Europe. One of the most noticeable of local winds is the *Simoon* (Arabic, hot and poisonous)—a hot suffocating blast, that occurs in most countries bordering on sandy deserts, especially in certain parts of Asia and Africa, where its temperature has been noted as high as 120 and 130 degrees. Coming from the arid desert, and laden with the minutest particles, it often gives a reddish colour to the atmosphere, and thus forewarns the traveller to take shelter from the approach of its pestilential breath. In Turkey it is called the *Samieli*; in Egypt, *Khamsin*, (fifty), because it usually continues fifty days; and in Guinea and Senegambia, *Harmattan*. The *Sirocco* (Arabic) is another hot, parching wind, that occasionally passes over Sicily and adjacent districts, and is supposed to originate in the Sahara, or great burning desert of Africa. The *Solano* (Lat. *sol*, the sun) is a similar south-west wind that occasionally visits the Spanish peninsula, and blowing from the direction of the African deserts, is regarded as a modified sirocco. The *Föhn* of Switzerland (Lat. *favonius*, south-west wind) is a further local modification of the same aerial current, whose warm influences sometimes cause rapid and destructive meltings of the Alpine snows and glaciers.

234. In Buenos Ayres, *Pampero* is the name given to a violent west wind, which, traversing the arid plains of the Pampas, raises whirlwinds of dust, and carries them forward to the coast of the Atlantic. The pamperos seem to be portion of the return or north-west trade-winds. In Peru, between the Cordilleras and the Andes, at the height of 12,000 feet, are vast tracts of desolate table-land, known by the name of the *Puna*. These regions are swept for four months in the year by piercing cold winds (the *Puna winds*)



Dust or Sand Storm.

from the snowy peaks of the Cordilleras, which are so extremely dry, and absorb moisture with such rapidity in their passage, as even to prevent putrefaction in dead animal bodies. A similar north-east mountain wind, under the name of *Bise* (Fr.) descends in spring and early summer from the snow-covered Alps, and occasionally carries its chilling influences far into the southern provinces of France.

Storms.

235. In addition to the variable winds already noticed, which either recur at tolerably regular intervals, or are confined to definite tracts upon the earth's surface, there occur in all countries violent commotions in the atmo-

sphere, generally sudden in their appearance and most destructive in their effects. These are usually classed under the general title of *Storms*. Like all other winds, they are due to the aerial currents set up by a want of equilibrium between the weight of the atmosphere in adjoining areas. When from some cause the air in any locality becomes rarefied, it ascends, and the weight of the atmospheric column below is diminished. The colder and denser air of the surrounding areas at once rushes in from all sides to supply the deficiency, and a wind is generated, of an intensity proportioned to the difference between the atmospheric pressures, which continues until equilibrium is restored. These incoming currents of air do not pass in straight lines to the centre of the area of low atmospheric pressure, but circle round it in an ever-narrowing spiral, gradually ascending as they approach the centre. Here their mutual pressure causes a calm, and they rise and flow upwards and outwards into the higher regions of the atmosphere. This incoming spiral or vorticose movement is termed a *Cyclone* (Gr. *kuklos*, a circle or whirl); while the corresponding outflowing motion from the areas of high pressure is termed an *Anticyclone*. In the northern hemisphere the rotation of the currents of air in a cyclone is from right to left, contrary to that of the hands of a watch. This, like the direction of the movement of the trade-winds already explained, is a necessary result of the earth's rotation from west to east. The incoming air-currents start from all directions towards the centre of the cyclone, and were the earth stationary, they would all meet and neutralise each other at the centre; but as the velocity of rotation of the earth's surface decreases as we pass from the equator to the poles, the wind approaching the disturbed area from the south reaches it with a greater easterly velocity than that of the latitude, and thus makes its appearance as a south-west wind. For a corresponding reason, the northerly currents arriving with a less easterly velocity than that natural to the area, appear to lag behind, and thus form a north-east wind. In this way a gyratory movement of the air is set up, the direction of which is from left to right. In the southern hemisphere, for a corresponding reason, the cyclone rotates from right to left. In addition to this rotatory movement, cyclones have a generally progressive

movement in some definite direction, the centre of the storm moving onward at a rate of from 15 to 30 or even

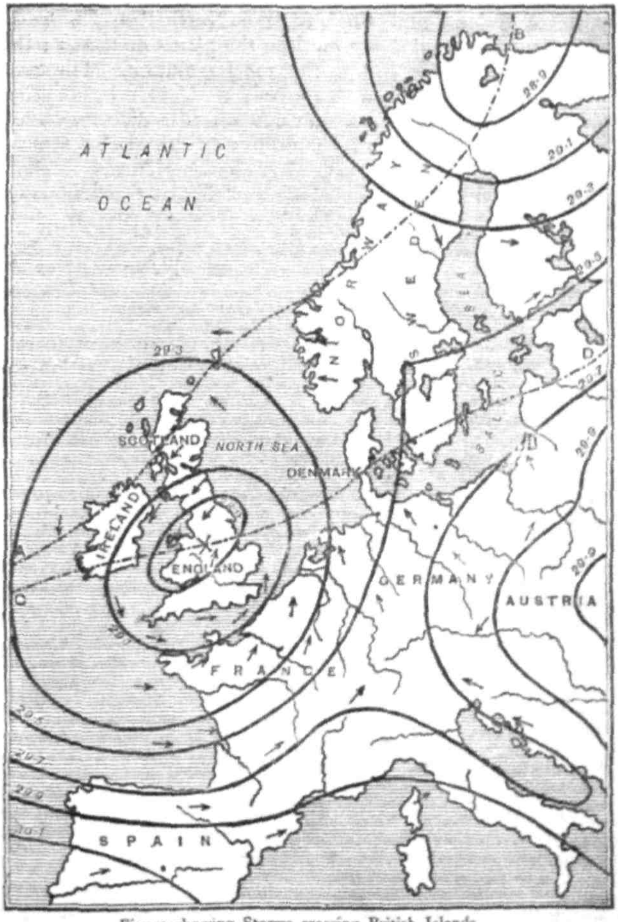


Figure showing Storms crossing British Islands.

45 miles an hour. With very few exceptions, British storms

come from off the Atlantic Ocean—the centre of the storm area passing north of Ireland and Scotland, and leaving Europe by way of the North Cape; or crossing the central parts of Ireland and England, the North Sea, Denmark, and the Baltic, and dying away in the plains of Russia: the former direction is by far the most common. The area of country affected by a storm is of a circular or elliptical shape, and is seldom less than 600 miles in diameter, averaging twice that amount. The force of the wind is strictly proportioned to the difference between the barometric pressure at the centre of the cyclone and that of the neighbouring areas: where that difference is small, the resulting breeze is light; where it is large, the wind increases to a gale, blowing with a velocity of from 60 to 70 miles an hour, while occasional gusts may have a speed of from 100 to 150 miles in the same time.

In the accompanying figure (p. 213) we have a synchronous chart of Western Europe, showing the barometric pressure and the direction of the wind when a storm is passing over the British Islands. The dark circles represent lines of equal barometric pressure, and are drawn through those points where the weight of the atmosphere is the same. From the arrangement of these lines upon the map, it will be seen that we have here evidence of two cyclones and two anticyclones. One of these cyclones (or storm-areas of low barometric pressure) is partly seen passing off into the Arctic Ocean to the north of Norway, having previously travelled across the north of Scotland and Ireland, along the dotted line A B. A second cyclone forms a storm-area extending completely round the British Islands, having its centre about the middle of England, and travelling slowly north-eastward along the line C D. Portions of two anticyclones (or areas of high pressure) are seen in Spain and Austria, and from these the wind rushes in in a spiral course to the storm-area of Britain. From the disposition of the small arrows, showing the direction of the wind, it is clear that the atmosphere surrounding the British Islands is whirling round in a spiral form from left to right,—blowing eastward in the Channel, northward in the German Ocean, westward in Scotland, and to the southward in Ireland. The winds blow their fiercest in the north of England, the Channel, and the

Bay of Biscay, where the barometric lines are crowded together, and the difference in the weight of the atmosphere in neighbouring localities consequently very great in amount. To the north and west of Ireland, and in central Norway and Sweden, the widening of the barometric lines shows that the atmospheric disturbance is small, and there, consequently, the winds are comparatively light and gentle. The most violent and destructive of these local storms are the *Hurricanes* of the tropical regions. These have

Fig. 1.

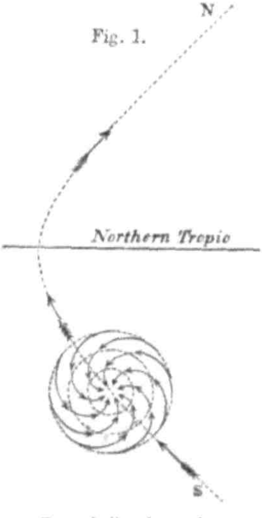


Fig. 1.—General direction and rotation of Hurricanes in the Northern Hemisphere.

Fig. 2

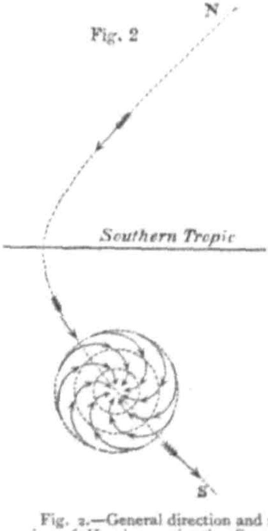


Fig. 2.—General direction and rotation of Hurricanes in the Southern Hemisphere.

been most fully studied in the North Atlantic, where they generally follow a north-west course roughly parallel to the curved line formed by the seaward edges of Hayti, Cuba, and Florida. They blow with a velocity of from 80 to as much as 150 miles an hour, hurling the waters of the ocean upon the land, and committing the most fearful devastation in their course. The corresponding hurricanes of the southern hemisphere cross the central

parts of the Indian Ocean in a south-westerly direction towards the island of Madagascar. The name *Typhoon* is given to similar hurricanes which occur in the China Sea and its neighbourhood, from June to October. They generally sweep in a south-west direction parallel with the coast of China, dying out as they reach the confines of the Indian Ocean. In all these hurricanes the same law of rotation obtains as that already indicated—the storms of the southern hemisphere rotating with the sun, those of the northern hemisphere moving in the contrary direction. The phenomena known as Whirlwinds, Tornadoes (Span. *tournar*, to turn), are merely local and violent cyclones of small diameter. Their occurrence at sea produces *water-spouts*, and on the sands of the desert *sand-pillars, sand-storms*, &c. Some of these whirlwinds have their origin in the meeting of contrary winds, and their direction of rotation is determined by the relative strength of the opposing currents. Others are caused by the eddies formed between the ascending columns of air rising from neighbouring spots unequally heated by the rays of the sun.

Dew, Fogs, Rain, and Rainfall.

236. Closely connected with the winds, and greatly influenced in their character by them, are the dews, rains, snows, and other aqueous phenomena which enter so largely into the determination of climate. The consideration of these subjects belongs especially to the province of Meteorology, but as much may be here summarised as will enable the learner to trace their connection with his immediate study of Physical Geography. As already stated, insensible vapour to a greater or less amount is always present in the atmosphere as one of its accidental ingredients. The warmer the air, the greater its capacity for this moisture; hence the greater amount taken up during the heat of the day. After sunset the earth loses much of its heat by radiation. The lowest stratum of the air in contact with the ground is cooled by it. Its point of saturation is consequently lowered, and it deposits that portion of its moisture which it is no longer able to retain in the gaseous state in the form of *dew*. Dew is therefore the moisture insensibly deposited from that

stratum of the atmosphere in contact with the surface of the earth; and what is termed the *dew-point* is that temperature of the atmosphere at which it is no longer able to retain the whole of its moisture, and some of it begins to be precipitated. Dew never begins to be deposited upon the surface of any body until its temperature is below the dew-point of the contiguous atmosphere; and the quantity deposited depends chiefly upon the humidity, serenity, and tranquillity of the atmosphere, as well as on the constitution, surface, and locality of the bodies receiving the moisture. Still, clear nights are more favourable for the deposition of dew than windy and cloudy ones; and all substances like fur, silk, wool, grass, &c., whose radiating power is great and conducting power small, are naturally most copiously bedewed; while substances like rocks and soils, which possess opposite qualities, contract but little dew. In temperate zones, where the frequent interchange of sun and shower preserves the earth from the extremes of heat and moisture, very little dew is deposited. In tropical regions, where the day-heat is extreme, the saturation-point of the atmosphere is excessively high, while the unclouded sky at night allows of uninterrupted terrestrial radiation. The rapidly cooled ground soon reduces the lower strata of the atmosphere below the dew-point, and the dews are copious and abundant. As no rain falls for months, these dews are most refreshing. But for this beneficent arrangement many intertropical countries would be altogether sterile and barren of vegetation.

237. When the temperature of the air is reduced below the point of saturation, the vapour which it is no longer able to retain in a gaseous state becomes visible, and appears as *fogs*, *mists*, and other kindred phenomena. These fogs occur most abundantly along the courses of rivers, on mountain-sides, over shoals and banks at sea, and generally along the seaboards of continents and islands; and this obviously in consequence of the unequal temperature of the contiguous land and waters. Like dews and rains, fogs exercise a refreshing influence on vegetation; and in some countries, like Peru, their occurrence (the *garuas* or sea-fogs) is periodical and regular. *Clouds* have been defined as "masses of visible aqueous vapour which float in the sky, or drift through it with the wind, assuming every variety of colour and form." As clouds, they exercise but an indirect

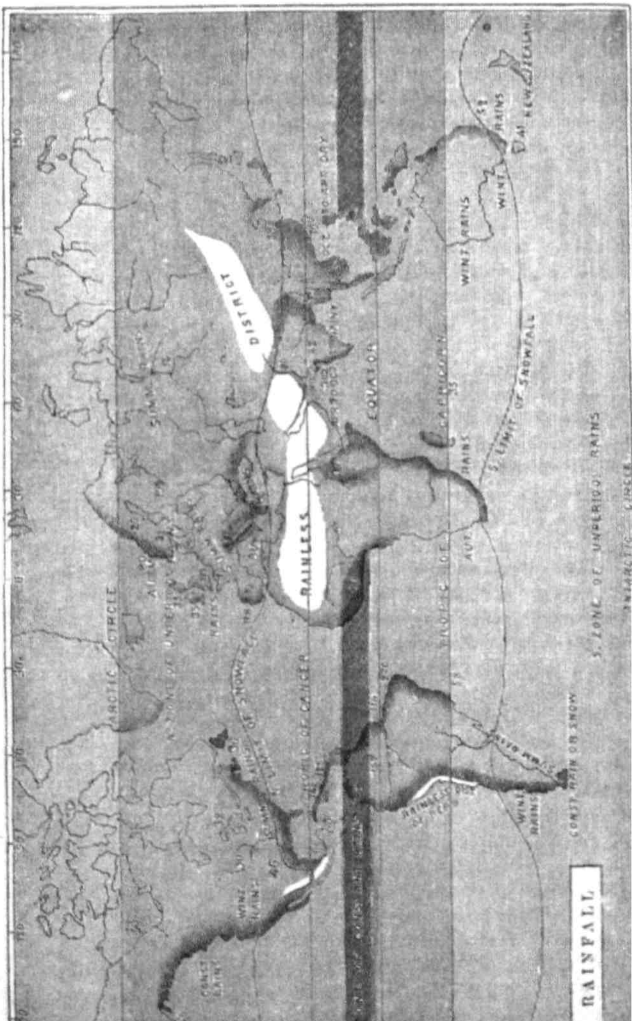
effect on terrestrial climate (by hindering the nocturnal radiation of heat); and it is only when they break, by further condensation, into rain, snow, and hail, that they come directly within the province of the geographer.

238. The precipitation of water from the atmosphere in the form of *rain* depends chiefly on the further condensation of clouds and fogs by the commingling of colder and warmer currents. The capacity of air for moisture decreases at a faster rate than the temperature, and thus the mingling of two currents only slightly differing in temperature may so reduce this capacity that heavy rainfalls will take place even where there is no great decrease in atmospheric warmth. Where the temperature of the air falls below the freezing-point (32° Fahr.), the atmospheric vapour may be converted into *snow;* or if rain has been already formed in the upper air, the drops in passing through strata beneath the freezing-point will be converted into *hail.* Rain, hail, and snow are thus to a certain extent convertible phenomena; hail occurring in all latitudes and climates, but snow only in the colder latitudes, and at elevations where the thermometer continues below 32°. Winds being the great natural agents by which the colder and warmer masses of the atmosphere are brought into combination, rains will occur most frequently where these currents are shifting and variable. Where the winds are constant and of equable temperature, rain seldom happens, unless at points where these currents impinge on lofty mountains, and carry up the air of the sea and plains into the colder regions of the atmosphere. As the capacity of the air for moisture increases with the temperature, it must happen (other things being favourable) that the amount of rainfall is greater in warm than in cold latitudes, as the air of the former is capable of holding a larger quantity of aqueous vapour, and greater also in low-lying areas than upon elevated table-lands for a corresponding reason.

239. For the foregoing reasons the amount of rainfall is greatest within the tropics, and decreases as we advance north or south into higher latitudes. It is also greater at the sea-level and moderate elevations than it is on lofty table-lands. In like manner more rain descends upon the coasts than upon the central regions of a country—the humid air from the ocean gradually parting with its moisture

as it is borne farther and farther inland. In Britain, for example, where the prevalent winds are from the Atlantic, the annual rainfall on the west coast is about 37 inches, while on the east side of the island it rarely exceeds 25 inches. To these it may be added, that a country thickly clad with forest-growth (other things being equal) receives a greater amount of rainfall than one destitute of wood—the proportion, from experiments conducted in the forest of Halette, in France, being 192.5 for the forest, and 177 for the open country. It must be observed, however, that though the annual rainfall within the tropics is greater than in higher latitudes, the number of rainy days are fewest within the tropics, or where the winds are constant—and most numerous in the higher latitudes, where the winds are shifting and variable. Thus, between 12° and 43° N. lat., the number of rainy days is stated at 78; between 43° and 46°, 103; between 46° and 50°, 134; and between 50° and 60°, as many as 161. Of course, since the rainy days are fewer in low latitudes, and the annual amount of rainfall greater, the rains must be much more powerful—a fact sufficiently recorded by all travellers in tropical regions.

240. Understanding these principles, and bearing in mind what was stated regarding the constant, periodical, and variable winds, the learner will readily perceive,—1. Why heavy and frequent rainfalls should take place within the so-called zone of calms, where evaporation is excessive, and the air often gusty and variable; 2. Why rain should seldom fall at sea within the region of the steady and equable trade-winds; 3. Why the rains within the range of the monsoons should be periodical, and the year divided into two seasons, a wet and a dry; 4. Why the rains in the higher latitudes should occur at no fixed period, but be irregularly distributed throughout the year; 5. Why some regions, like the central districts of Africa and Asia and the coasts of Peru, should be altogether rainless; and 6. Why almost constant rains should occur in some countries, like Guiana—while in others showers of excessive violence should occasionally fall, adding to their annual rainfall as much in the space of a few hours as ordinarily happens during the course of many months. As may be expected, the annual rainfall of these various regions will differ very widely; and will be attended, of course, by proportionate results—heavy falls being bene-


RAINFALL
RAINLESS
DISTRICT
EQUATOR
TROPIC OF CANCER
ARCTIC CIRCLE
S. LIMIT OF SNOWFALL
S. ZONE OF UNPERIODIC RAINS

ficial in hot countries, and moderate supplies in temperate and milder zones. In the British Islands the annual fall (as ascertained by rain-gauge) ranges from 24 to 70 inches, or has an average of about 47 inches; while in tropical countries the mean is upwards of 200 inches. As much, however, as 229 inches has been noted in Dutch Guiana, 276 in Brazil, 13 feet during 140 days in Patagonia (Dr King), 302 inches at an elevation of 4200 feet in the Western Ghauts, south of Bombay; and in the Khasia Mountains, at the head of the river-flats or Jheels of Bengal, upwards of 600 inches, or 50 feet, have been registered by several observers. At the same place, Dr Hooker has recorded 30 inches in twenty-four hours; 21 inches have been noted at Cayenne during the same period; and 23 inches are not uncommon near Port Jackson in New South Wales.

241. Extending the facts alluded to in the preceding paragraphs, the rainfall of the globe may be arranged under three great heads,—the periodical of the tropics; the variable of the higher latitudes; and the abnormal of certain districts, where it occurs either in excess or is altogether absent. Within the tropics the rainy season commences at the shifting of the monsoons; and as this change is dependent upon the position of the sun, it begins earlier in those regions that lie near the equator than in those more remote. In general terms, the rainy season in the northern half of the torrid zone may be said to commence with April and last till October, while the dry season extends from October till April. In the southern half this order is reversed—the dry season embracing from April till October, and the season of rain from October till April. In Africa, for instance, near the equator, the wet season begins in April and continues till October; while in Senegambia it does not commence till June, and then lasts till November. In India, on the Malabar coast, the rains commence early in May, but do not reach Delhi till near the end of June. In the New World, also, the rain falls at Panama early in March, but it seldom appears in California before the middle of June. Of course, within the tropics as elsewhere, the regularity of the periodical rains is interrupted by the configuration of the land, mountain-chains, and similar causes; and hence the peculiarities that mark the times as well as intensities of the wet and dry seasons of such areas as the east

coast of Africa, the Red Sea, the Malabar coast, the Coromandel coast, and the coasts of Australia. On the Malabar coast, for example, the south-west monsoon (coming from the humid region of the equatorial ocean to supply the place of the highly rarefied air of the heated continent) is said to be "ushered in by terrific storms of thunder and lightning. The waters pour down in torrents, and when the thunder has ceased, nothing is heard for several days but the rush of the descending rain, and the roar of the swelling streams. In a few days the storm ceases, and the earth, which before was withered by the glowing atmosphere of the dry season, is now, as if by magic, suddenly clothed with the richest verdure; the air above floats pure and balmy, and bright tropical clouds sail tranquilly through the sky. After this the rains fall at intervals for the space of a month, when they again return with great violence. In July they attain their height, and from that time gradually subside until the end of September, when the season closes as it began, in thunders and tempests." On the eastern or Coromandel side, the order of things is reversed. The south-west monsoon, in passing over the Western Ghauts and the central table-land of the Deccan, parts with all its moisture, and reaches the eastern side as a hot, dry wind; and it is not till the north-east monsoon begins to prevail in October that the rainy season is experienced on the coast of Coromandel.

242. Beyond the tropics the rains no longer occur at stated periods, but become *variable*—that is, are distributed throughout the year in a very irregular and uncertain manner. In some countries they occur most frequently in winter; in some, in spring and autumn; and in others, again, most abundantly in summer. Thus, the amount that falls in the west of England in winter is said to be eight times greater than that in summer; in Germany the winter and summer amounts are about equal; but in St Petersburg the winter fall is little more than a third of what descends in summer. Again, in Britain, there are more rainy days in winter than in summer; but in Siberia it rains four times as often in summer as in winter. The countries of Europe bordering the Mediterranean are generally regions of winter rains; while those of Western Europe are distinguished rather by the abundance of their autumnal rains. In

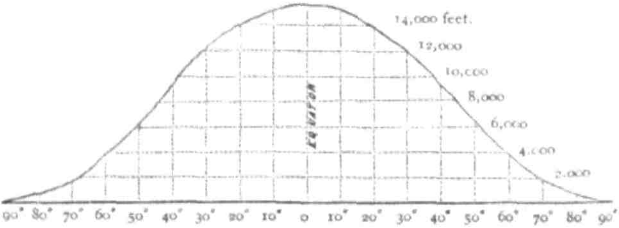
Europe, north of the Alps, the north-east winds (as coming from the higher and colder latitudes) are comparatively dry; while those from the south-west (from the humid expanse of the Atlantic) are warm and laden with moisture. On the eastern coast of North America the reverse holds good, and the north-east winds borne from the ocean give rise to the long-continued rain-storms of spring and autumn.

243. As might be expected, the districts of *excessive rainfall* lie within the tropics, and mainly in the immediate neighbourhood of the equator. In the New World, Brazil, Guiana, the West India Islands, Central America, and the shores of the Mexican Gulf, are all notable for their heavy and continuous rains; while in the Old World, the coasts of Guinea and Senegambia, Eastern Africa, India, and the Indian Archipelago, are remarkable for similar phenomena (see Map of Rainfall). As some regions are celebrated for their rainy character, so others are equally remarkable for the entire absence of rainfall. Of these *rainless tracts* the more noted are the great desert-lands of Africa, Arabia, Persia, and Mongolia—an almost continuous area, varying in breadth from the 15th to the 47th parallel, and in length from 16° west to 118° east longitude. Except on its borders, this vast expanse is all but absolutely rainless, the prevailing winds blowing out of it in all directions in winter; while in summer its heated atmosphere readily absorbs and converts into invisible vapour whatever humidity may be carried towards it from adjacent regions.

Hoar-frost, Hail, Snow, &c.

244. Of the other aqueous phenomena more immediately bearing on climate, the limits of an introductory sketch will only permit the briefest allusion to hoar-frost, snow, hail, and those accumulations of frozen water known as glaciers and icebergs. *Hoar-frost* (or *white-frost*, from its crisping the grass and foliage with minute snowy crystals) is produced in the same manner as dew, and occurs chiefly in early spring and autumn, during serene nights, and when the surface of the earth falls below the freezing-point. Whatever prevents the rapid radiation of heat (overhanging foliage, passing clouds and currents) arrests the formation of hoar-frost, which is often very destructive to tender

plants and to buds and blossoms in early spring. *Snow* is the frozen moisture that descends from the atmosphere in minute feathery crystals, when the temperature of the air is at or below the freezing-point of water. Of course, at the sea-level within the tropics, and for fifteen or twenty degrees beyond them in either hemisphere, snow is unknown (see Rain and Snow Map in Atlas); and it is only during winter that it falls in the higher latitudes, and at considerable elevations in the tropics. In the polar regions, and at extreme heights in all latitudes, it becomes perennial; and this limit at which it remains unaffected by the heat of summer is known as the *snow-line*, or less accurately, perhaps, as the line of *perpetual congelation*. The lower the latitude—that is, nearer the equator—the higher the snow-line, which descends constantly, but somewhat irregularly, according to the nature of the situation, as we proceed towards either pole. The following diagram will convey some idea of its gradual descent from 16,000 feet at the

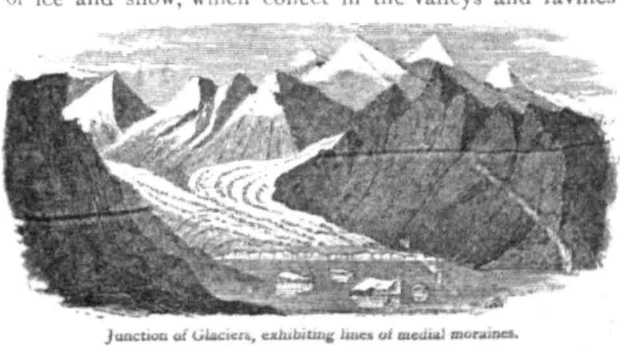


Curve of the Snow-line according to Latitude.

equator down to the sea-level at the poles. Greenland and the Palæocrystic Sea are examples of these perpetually frozen areas—the former being the land of snow and glacier which are ultimately launched as the iceberg—the latter as the sea which is more or less encumbered by floes that are either generated on its surface or accumulated along its shores. From the equator to latitude 20° there is little variation in the height of the snow-line, unless there be some peculiarity as regards winds and moisture in the situation; but from 20° to 70° the descent is very rapid, and the limit rapidly approaches the sea-level, as was formerly noted in Chap. VI., on Mountains and Mountain-Systems.

245. Hail occurs in all latitudes and at all seasons; and though the producing causes are not always discernible, it seems mainly dependent on the meeting of an intensely cold current of air with a much warmer and nearly saturated current—the temperature of the united mass being suddenly reduced below the freezing-point, as well as on peculiar electrical conditions of the atmosphere. Hail falls in pellets from the size of a pea to that of a pigeon's egg, and is frequently of an irregular and stellate or star-like form. Hail-storms are often very destructive, but luckily are always restricted to limited areas.

246. As snow must accumulate on all mountain-ridges above the snow-line, as well as on the surface of all polar lands within the limits of perpetually frozen ground, it will become more or less compressed, and this compression will be greatly augmented by its partial meltings in summer, as also by the falling and freezing of rain and other atmospheric vapours. From this accumulation, compression, and re-freezing, arise avalanches, glaciers, icebergs, and other kindred phenomena. *Avalanches* (Fr.) are accumulations of snow, or of snow and ice, which are frequently precipitated with destructive violence from lofty mountain-ridges, like those of the Alps, into the valleys and plains below. *Glaciers*, on the other hand, are accumulations of ice, or of ice and snow, which collect in the valleys and ravines



Junction of Glaciers, exhibiting lines of medial moraines.

of snowy mountains like the Alps and Himalayas, or on boreal uplands like those of Norway and Greenland, and which move downwards (the solid ice insensibly and mys-

teriously obeying the force of gravity, in the manner of a viscous or glue-like body) with a peculiar creeping motion, smoothing the rocks over which they pass, and leaving mounds of debris (*moraines*), lateral and terminal, as they melt away. In mountain-gorges, glaciers descend as ice-streams till, coming below the snow-line, they begin to melt and disappear; but on polar lands, where they cover almost the entire surface, they move downwards to the sea-shore, and there their advancing fronts break off and are floated away as *icebergs* (ice-mountains) and *ice-floes* (ice-islands). Such ice-masses have been met in the Arctic and Antarctic Oceans several miles in circumference, rising from 40 to 200 feet above the water, and loaded with stones and shingle. Some idea of their size may be formed from the fact that little more than a tenth of their bulk rises above the water, the specific gravity of ice being only 0.9. As they are floated by the polar currents to warmer latitudes they melt away, dropping their burden of boulders and debris on the bottom of the ocean. "Fields" and "packs" of such ice are familiar phenomena both in arctic and antarctic waters—the bergs of the north being seldom carried southward in the Atlantic beyond the 44th parallel of latitude, while those of the south are not unfrequently found northward as far as the Cape of Good Hope, or, on an average, at 10 degrees lower latitude.

247. As climatological agents, snow and ice have considerable influence on the regions in which they occur. Accumulating on mountain-heights, they are the perennial sources of the springs and streams that descend to refresh and fertilise the thirsty lowlands; while in tropical countries the winds that pass over them are cooled, and flow downwards to temper the sultry atmosphere of the plains below. Masses of floating ice are productive of similar results, the seas and coasts in their vicinity being cooled by their presence, and fogs and rain-storms generated as they melt away. In the higher latitudes, on the other hand, where the winters are severe, snow, from its slow-conducting properties, forms a warm covering for the soil (the *snow-blanket*, as it is termed by farmers), and greatly defends vegetation from the rigour of the frost. Within the polar circle, also, the darkness of the long winter is considerably diminished by the *snow-sheen* or *snow-blink*—snow reflecting the faint light that

there proceeds from the sky. The grinding, grooving, and smoothing effects of glaciers on rock-surfaces, and the rock-transporting powers of icebergs, are facts now well known to Geology; and though their consideration belongs more immediately to that science, the results now and in time past cannot be altogether overlooked by the student of Physical Geography.

Causes affecting Climate.

248. In its technical sense, the term *climate* (Gr. *klima*, an inclination) denotes an imaginary belt of the globe parallel to the equator, and was so called by the earlier geographers, because the differences of these climes depend on the inclination or obliquity of the sphere. Between the equator and the polar circle there were twenty-four such climatic belts—each depending on the increasing length of the day (half an hour's increase for each belt), and of course expanding in breadth from the equator towards the poles. From the polar circles to the poles there were six climes—the differences of the longest day in their case being counted by monthly periods instead of half-hours. The term is now employed in a much wider sense, as embracing the entire *weather-conditions* of any district, and as such we shall now proceed to consider its relations. Although the climate of a locality is mainly dependent on its heat and moisture, yet so many circumstances tend to disturb and modify these conditions, that the subject becomes extremely complicated and difficult of determination. Latitude, height above the sea, distance from the ocean, nature of soil, distribution of land and water, direction of mountain-chains, winds and rains, currents of the ocean, cultivation, and the like, all exert their influence in modifying the weather-conditions or climate of any special locality.

249. As repeatedly stated, the main element in climate is the amount of heat received by the sun, and this diminishes (par. 216) according to the latitude, or distance from the equator. Owing, however, to the obliquity of the earth's axis, the regularity of this decrease is alternately interrupted in either hemisphere, and the respective length of day and night at opposite seasons becomes an important element in

climatic diversity. Within the tropics day and night are all but equal—the longest day being little more than thirteen hours, and the shortest nearly eleven. In the latitude of Greenwich the longest day is nearly seventeen hours, and the shortest only seven; while, within the polar circles, there is a brief summer period when the sun never sets, and a corresponding winter season when he never rises. The year, within the tropics, is divided into two seasons—a wet and a dry. The latter is regarded as the summer, and the former as the winter; but they are in direct opposition to the astronomical seasons, as the rains (par. 241) follow the sun. In some intertropical countries, as the West Indies, there are two rainy seasons and two dry seasons within the year. In the temperate zone, again, the year is divided into four seasons — spring, summer, autumn, and winter; but this regular succession of climatic change can hardly be considered as extending farther than from the 35th to the 60th parallels. In the frigid zones, on the other hand, only two seasons are known—a long and severe winter, during a portion of which the sun never rises above the horizon, and a brief but fervid summer, when that luminary never sets. From these circumstances it will be at once perceived that the torrid zone is the region of greatest heat throughout the year, with comparatively little difference between its seasons; that the temperate zones stand next in order as regards the annual amount received, but they experience great difference of temperature during the successive seasons; and that the frigid zones are regions of small annual heat, and at the same time are subjected to seasonal extremes. Such is the general climatic order as regards latitude; though in the southern hemisphere, owing to the smaller extent of land, the decrease of heat as we depart from the equator is more rapid than in the northern—so that, on a general average, the latter is about 3½° warmer than the former.

250. Altitude is the next great modifier of climate, but owing to many correlative circumstances (prevalent winds, slope, proximity to the sea, &c.), its operation is not altogether uniform. As formerly stated, a decrease of 1° Fahr. takes place in the lower regions of the atmosphere for every 300 or 350 feet of ascent; but at great heights and in extreme latitudes the decrease is more rapid. As it is, under

every latitude the loftier mountains (Himalayas, Alps, Andes, &c.), are perpetually covered with snow; the higher plateaux (Mexico, Bolivia, Armenia, Tibet, &c.) are several degrees colder than the contiguous lowlands; and in temperate zones such table-lands experience much greater extremes of summer's heat and winter's cold than the surrounding districts—having, like Spain, Armenia, and Persia, summers of tropical heat and winters of almost polar severity. Another great cause of modification is the unequal rate of heating and cooling of the land and water surfaces (par. 218), by which islands and sea-coasts are rendered cooler in summer and warmer in winter than inland tracts—creating what has been termed *insular* and *continental climates*. Britain, New Zealand, and Tasmania enjoy, in this respect, insular climates; Germany, central Russia, and Tartary, continental ones. Connected with this, and depending on the set of the trade-winds and ocean-currents, may be noticed the observation of Humboldt, that the continents and larger islands in the northern hemisphere are warmer on their western than on their eastern sides; while in the southern hemisphere the reverse holds good—the western being the colder and the eastern the warmer.

251. It would exceed the limits of an introductory outline to describe in detail the many causes concerned in the modification of climates; but besides those of latitude, altitude, and proximity to the sea, may be noticed the following:—

1st, The direction of mountain-chains, which, by intercepting cold winds, render the countries on one side warmer than those of the other; and in like manner, by intercepting moist winds, favour the production of rain on the windward, and droughts on the leeward, slopes of sheltered declivities. The eastern slopes of the Andes, for example, intercept the humid trade-winds from the Atlantic; their counter-slopes on the Pacific side are arid and rainless.

2d, The general inclination or slope of a district, as this may lie to the heat of the morning and noonday sun, or be turned to the feebler rays of his afternoon and evening declension.

3d, The prevailing winds of a region, as these may be cold or warm, dry or humid. The westerly winds of our own island are humid and warm—the easterly are cold and

through places having the same winter temperature, *iso-cheimōnal lines* (Gr. *isos*, and *cheimon*, *cheimōnos*, winter); and those connecting places of the same mean annual temperature, *isothermal lines* (Gr. *isos*, and *thermē*, heat). The difference between the summer and winter temperatures may amount to 2, 20, 40, or more degrees of Fahrenheit; but the isothermal lines show the mean amount of heat received throughout the year, and, of course, are the most correct indicators of the general climatic conditions of any given locality. In the accompanying Sketch-map the isotherms are laid down for every ten degrees, and their bendings northward and southward (according to distribution of land and water, altitude, distance from sea, &c.) convey to the eye instructive proofs of the operating causes adverted to in the foregoing paragraphs.

RECAPITULATION.

253. In the preceding chapter attention has been directed to the Climatology of the Globe—that is, to those weather-conditions on which its vegetable and animal life are so intimately dependent. The main medium of climate being the Atmosphere, it was necessary to advert to its nature and composition as an integral portion of our planet. As an aerial fluid it consists of an admixture of 79 parts nitrogen and 21 oxygen, together with a small but variable proportion of carbonic acid gas, traces of ammonia, &c., and always holds in suspension more or less of aqueous vapour in a visible or invisible form. Constituted as plants and animals are, this composition is indispensable to their existence—the latter consuming oxygen and exhaling carbonic acid; the former, in counterbalance, decomposing carbonic acid, assimilating the carbon and setting free the oxygen. Light and invisible as this aerial envelope may appear, it exerts a pressure on the earth's surface, at the sea-level, of about 14¾ lb. avoirdupois to the square inch—a pressure which is balanced by a column of mercury 30 inches in height, or by one of water 34 feet in height; hence the

barometric column of the meteorologist, and the *rise and fall of the barometer* according to changes in the weight of the atmosphere. As an elastic or compressible medium, its lower strata are denser or heavier than those at great elevations; and as its capacity for heat and moisture decreases with its rarity or attenuation, the higher regions of the air are colder and drier than those at a lower elevation.

254. As the medium through which the light and heat of the sun are conveyed to the terraqueous surface, the atmosphere—partly owing to the varying inclination of the sun's rays, but mainly to the fundamental differences in the mode of reception and radiation of heat by land and water—becomes variously heated in its different regions, and hence arise winds or aerial currents,—the warm air of one locality expanding and ascending, and the colder and heavier rushing in from all sides to supply the deficiency. The winds thus generated assume various physical characteristics—the chief cause of modification being the different amount of heat received by the different zones of the earth—and various directions; their initial courses, which are due solely to the action of gravity, being affected by the rotation of the earth. Thus some are said to be *constant*, as the trade-winds of the tropics; others *periodical*, as the monsoons and the sea and land breezes; and others, again, *variable* and irregular, as the winds of the higher latitudes. In their physical characters they are governed chiefly by locality and the nature of the region from which they blow, and are thus hot or cold, moist or dry, relaxing or invigorating,—floating as a zephyr that scarcely disturbs the thistle-down, or sweeping as hurricanes that uproot forests and overturn buildings.

255. The warmer the air the greater its capacity for moisture; but in every case there is a point beyond which it is incapable of sustaining more vapour in an invisible form. It is then said to be *saturated*, and in this state any cooling, by coming in contact with the colder earth, or by the con-

tact and commingling of colder aerial currents, produces condensation into dews, fogs, rains, snow, hail, and other kindred phenomena. These aqueous phenomena,—whether descending as *dew* from the unequal temperatures of the earth and air—as *fogs* and *mists* from unequal temperatures of aerial strata—or as *rains*, by more sudden condensation, —are all essential to the vegetable and animal economies. Rains, like the winds on which they mainly depend, are almost constant within certain equatorial districts; periodical within the regions of the monsoons; and irregular in all the higher latitudes. Some tracts, as the Sahara, Egypt, Arabia, Persia, Mongolia, and Peru—are rainless, or all but rainless; but in most countries the rainfall, though varying from month to month and year to year, is, in the long average, pretty regular and persistent. It will vary, of course, according to latitude, direction of prevailing winds, proximity to the ocean, direction of mountain-chains, and the like; hence its great difference, even on opposite sides of the same island,—annual falls within temperate zones varying from 10 to 80 inches, and within tropical, from 100 to 500 or 600 inches.

256. When the temperature of the air falls below the freezing-point, fogs and mists are converted into snow, and rain into hail—*snow* being mainly an extra-tropical and winter precipitation, *hail* occurring in all latitudes and at all seasons of the year. Within the tropics, at the level of the sea, snow is unknown; in temperate zones it falls less or more during winter; but in polar regions and at great elevations above the sea, its presence is perennial in all latitudes. The altitude at which snow remains unaffected by the heat of summer (the *snow-line*) varies with the latitude—descending from 14,000 or 16,000 feet at the equator to near the sea-level at either pole. The latitudinal limit, north and south (the *snow-limit*), varies also according to the distribution of sea and land—receding and advancing as either element prevails. The perpetual presence of snow

and ice on lofty mountain-ridges and polar uplands gives rise to *avalanches*, *glaciers*, and *icebergs*,—phenomena whose geological influences are not less apparent than their climatological. The causes which affect the *climate* or weather-conditions of any locality are thus extremely varied—latitude, altitude, distribution of land and water, proximity to the sea, prevalent winds, direction of mountain-chains, slope, nature of soil, cultivation, and the like, all more or less exerting their modifying influences. Heat and moisture, however, are the great regulators of climate; and thus, in general terms, climatological zones may be said to decrease in importance from the equator to the poles. Nevertheless, this decrease by no means coincides with the parallels of latitude; hence, to determine the mean temperature of any locality, numerous thermometrical observations have to be made at hourly, daily, monthly, and yearly intervals. The results of such observations enable the meteorologist to connect places having the same summer, winter, and mean annual temperatures; and hence the scheme of exhibiting them at a glance by means of *isotheral*, *isocheimonal* or *isocheimal*, *isothermal*, and other lines.

XII.

PLANTS AND ANIMALS—THEIR DISTRIBUTION.

Life as affected by External Conditions.

257. HAVING noticed the general relations of the Land, Water, and Atmosphere, and the principal phenomena arising therefrom, we now turn to the Life by which they are respectively peopled. Hitherto we have dealt with the *inorganic* phases of nature; we have now to consider the *organic*. In the former case the study involved consideration merely of *chemical and mechanical forces* acting from without; now we have to deal with the superaddition of *vital action* operating through peculiar organs from within. Under the term *Life* is embraced all that appertains to the vegetable and animal kingdoms—subjects which belong to the domain of Botany and Zoology, and only come under the notice of Geography in as far as they are dependent on external conditions for their position or distribution on the globe. The origin, nature, and function of Life form the theme of Biology (Gr. *bios*, life); its distribution and external relations become important considerations in the study of Physical Geography, and the interdependence of Plants and Animals—their food, locality, specific change, and other vital phenomena—form some of the most interesting and subtle problems of Philosophy.

258. Whatever be the nature and origin of Life, it is clearly dependent for its continuance on the physical conditions by which it is surrounded. A little more heat or a little more cold, a little more moisture or a little more drought, and the plant flourishes or decays, the animal

increases or dies. It is obvious, then, that on a globe having different zones of climate, having regions of excessive humidity and regions of excessive drought—and having, moreover, different areas of land and water—life must be as diversified in its nature as the conditions under which it is destined to exist. The arrangement of plants into aquatic, terrestrial, and aerial—into flowering and flowerless—into trees, shrubs, herbs, grasses, mosses, lichens, sea-weeds, &c.—belongs to the province of Botany; and of animals into aquatic, terrestrial, and amphibious—into mammals, birds, reptiles, fishes, shell-fish, &c.—belongs in like manner to the province of Zoology. What the geographer has more especially to consider is their distribution over certain areas, the physical conditions apparently concerned in their restriction to these areas, and the dependence of the one kingdom upon the other, as completing the economy of nature. For the sake of brevity, the term *flora* (Lat.) is employed to designate the plant-life of a region or epoch, and the term *fauna* its animal life; hence we speak of the "Flora of South America" and the "Fauna of South America," as well as of the Flora and Fauna of the Tertiary, the Chalk, or any other geological period.

259. As far as the eye, or the eye aided by the microscope, can perceive, life is everywhere present—in the air, on the earth, and in the water, or even parasitic on and within other plants and animals. And yet, universal as life may appear, it is confined to the merest film of the terraqueous globe. A few thousand feet above the sea-level on land, and a few thousand feet beneath it in the waters, limit this *stratum of life* on either hand. Thickest at the equator, it thins out towards the poles; and densest near the sea-level, it becomes rarer and rarer the more it rises above or falls beneath this line of greatest intensity. Air, heat, light, moisture, and nature of soil, are the great regulators of life on the land; air, heat, light, depth, nature of bottom, and saline composition, the main regulators in the ocean. Were it not for these causes there is no reason why the same forms of life should not prevail in every region from the equator to the poles, and from the shore-line to the darkest abysses of the ocean. The influence, however, of external conditions is insuperable. The palm of the tropics would dwarf and die in the temperate zone;

the whale of the Greenland seas would perish in the waters of the equator; the rush that luxuriates in the marsh would wither if transferred to the arid upland; the shell-fish that swarm within the influence of the tides might die if submerged to the depth of a few hundred fathoms.

260. Every plant and every animal is therefore adapted by nature to the position it occupies, and within that position continues to fulfil its functions so long as the surrounding conditions remain unchanged. Why one genus or kind should differ from another genus man may never know; and at all events, the inquiry belongs to the general subject of biology, and not to that of geography. Again, why certain forms should only appear in certain regions—the kangaroo, for instance, in Australia, the ostrich in Africa, and the llama in South America—while other regions seem equally fitted for their residence, is a question involving considerations of origin, and of geological alternations of land and water in former epochs, that lie beyond the scope of our subject. What more immediately concerns geography, are the existing distribution of plants and animals, the conditions accompanying that distribution, and the question how far they are capable of being transferred to, and *acclimatised* in, other districts for the luxuries and necessities of man. Some tribes have naturally a wider range than others; some, again, have a more elastic constitution, and are capable of enduring greater diversities of climate; and others, obeying the instincts of food, procreation, &c., migrate from the unfavourable season of one region to the favourable season of another.

261. Of all animals man has the widest range—his superior intelligence enabling him to modify and overcome conditions that would be fatal to other creatures. Many, however, of the domesticated animals and cultivated plants have also considerable elasticity of constitution, and thus man has been enabled to carry them along with him in ever-increasing variety over the greater part of the habitable globe. In this way we require to distinguish between the truly *indigenous* or native products of a country, and the *exotic* or imported, though many species have been so long transferred and retransferred that it is now impossible to point to their original habitats. While, therefore, there is a natural apportioning of plants and animals to certain areas

and while external conditions are evidently the main regulators of this distribution, it must ever be borne in mind that man has already modified, and is continually modifying, this distribution, by transferring, cultivating, and destroying, according as his wants and wishes may compel. His operations, however, can never extend beyond certain limits; for over and above his control remain the great conditions of heat, light, moisture, &c., which ever govern the main geographical arrangements of plants and animals; and it is to these in particular that the limits of an introductory sketch will permit us to refer.

Plant Distribution—Terrestrial.

262. As already mentioned, heat, light, and moisture are the principal conditions affecting the terrestrial distribution of vegetable life. These conditions have their greatest intensity near the equator; hence the greatest exuberance of vegetation within the tropics, and its gradual declension as we proceed towards either pole. As might be anticipated, however, this declension is governed more by the isotherms than by the parallels of latitude—the mean amount of annual heat being the predominant condition in vegetable distribution, though the amount of summer heat (isotheral) has also much to do with its ripening and perfection. The mean annual temperature of two places may be the same, and yet the summer temperature of the one may be 10 degrees higher than that of the other, while the winter temperature may be 15 or even 20 degrees lower. Much, therefore, in Botanical Geography, depends upon the amount of heat which a plant receives during the period of its greatest activity, and this, in general, is regulated more by the monthly than by the annual isotherms. The zones of vegetation shading more gradually into each other than the astronomical zones (torrid, temperate, and frigid), botanists make a further subdivision of the earth's surface into equatorial, tropical, sub-tropical, warmer-temperate, colder-temperate, sub-arctic, arctic, and polar—each characterised by some peculiar feature, though partaking on either side of the forms that belong to the two adjacent zones.

263. 1. The *equatorial* zone, bounded by the isotherm of 79°, is characterised, wherever moisture is present, by its luxuriant vegetation. Succulent stems, large and showy flowers, gigantic parasites and climbers, arborescent grasses (canes, bamboos, &c.), orchids, palms, bananas, and the like, are typical of this belt, the greater portion of which, for reasons given in the preceding chapter, lies in the northern hemisphere.

2. The *tropical* zones, extending to the isotherm of 73½° on either side of the equator, are marked by palms, bananas, pine-apples, tree-ferns, species of fig, pepper-shrubs, cotton, coffee, tobacco, sugar-cane, &c.—there being fewer parasites and more underwood in the forests.

3. The *sub-tropical*, bounded by the isotherm of 63°, are characterised by a luxuriant growth of magnolias, laurels, myrtles, and figs, together with certain palms, zamias, cactuses, and arborescent euphorbias. In these zones, as in the damp regions of the preceding belts, vegetation is green throughout the year, and the climate, unless where rainless, is described as delightful.

4. The *warmer-temperate*, limited by 53½°, are still regions of evergreens, but are marked by the absence of palms—the dwarf palm of Europe, the palmetto of North America, and the Chilian palm, being, as it were, outlying forms from the sub-tropical zone. Deciduous forest-trees, oaks, chestnuts, &c., and figs, oranges, pomegranates, olives, and the vine, are typical of the warmer-temperate in the northern hemisphere; shrubby ferns, arborescent grasses, and araucariæ in the southern.

5. The *colder-temperate*, bounded by the mean annual temperature or isotherm of 42½°, is, in the northern hemisphere, the great zone of deciduous forest-trees, or those which shed their leaves in winter—hence the seasonal contrasts unknown in warmer regions. The characteristic vegetation of this zone is well seen in that of our own country, the north of France, and Germany—forests of coniferous trees (fir, pine, yew, &c.) and expanses of heath adding peculiar features to the area. The cultivation of wheat scarcely extends beyond this zone in the northern hemisphere; in the southern it is occupied chiefly by the ocean.

6. The *sub-arctic* zone, limited by the isotherm of 39°, is

characterised by coniferous trees (pine, larch, spruce, juniper, &c.), poplar, beech, grasses, and heaths; and on its northern limits, by birch, willow, and alder.

7. The *arctic* zone (which has no equivalent in the southern hemisphere, where the ocean alone prevails) is marked by the dwarf birch, alder, and willow; by occasional pines and firs; by grasses; and by numerous lichens and mosses on its northern limits. In the American section, rhododendron, andromeda, and azalea are not unfrequent.

8. The *polar* zone is characterised chiefly by its flowerless plants—lichens and mosses—though, during its brief summer, species of ranunculus, saxifrage, scurvy-grass, rush, willow, &c., make their appearance. In this zone there are no trees nor bushes, nor any cultivation of plants for food.

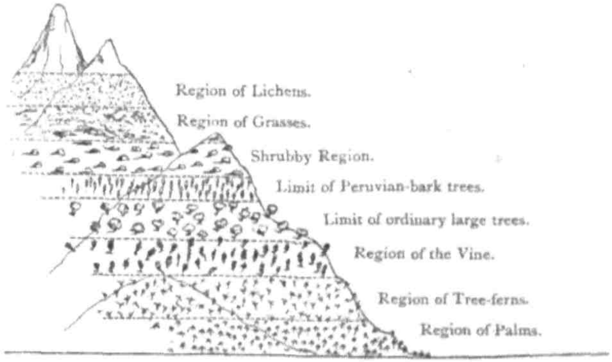
264. Such, in general terms, is the characteristic distribution of vegetable life as we proceed from warmer to colder latitudes. But the learner is already familiar with the fact, that temperature decreases not only as we proceed from the equator towards the poles, but also as we ascend from the level of the sea into the higher regions of the atmosphere. This ascent—*hypsometrical*, as it is technically termed (Gr. *hypsos*, height, and *metron*, measure)—is marked by analogous belts of vegetation; and at the equator, for instance, the traveller who ascends a lofty mountain passes through a flora much akin to that which marks the successive horizontal zones alluded to in the preceding paragraph. "We pass," says Herschel, "through the same series of climates, so far as temperature is concerned, which we should do by travelling from the same station to the polar regions of the globe; and in a country where very great differences of level exist, we find every variety of climate arranged in zones according to the altitude (hypsometrical zones), and characterised by the vegetable productions appropriated to their habitual temperature." Thus Humboldt, in describing the South American Alpine flora, remarks: "In the burning plains scarce raised above the level of the Southern Ocean we find bananas, cycads, and palms, in the greatest luxuriance; after them, shaded by the lofty sides of the valleys in the Andes, tree-ferns; and next in succession, bedewed by cool misty clouds, cinchonas (Peruvian-bark trees) appear. When lofty trees cease, we come to aralias (ivies) and myrtle-leaved andromedas (heaths); these are succeeded

by bejarias abounding in resin, and forming a purple belt around the mountains. In the stony region of the Paràmos, the more lofty plants and showy flowering herbs disappear, and are succeeded by large meadows covered with grasses, on which the llama feeds. We now reach the bare trachytic rocks, on which the lowest tribes of plants flourish. Paramelias, *lecidias, and leprarias (lichens)*, with their many-coloured thalli and fructification, form the flora of this inhospitable zone. Patches of recently fallen snow now begin to cover the last efforts of vegetable life, and then the line of eternal snow begins."

265. In temperate latitudes, though the variety of vegetation be less, and the lower zones of tropical flora be necessarily wanting, similar phenomena present themselves. "We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet-chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the height of 1950 feet the vine disappears; and at 1000 feet higher, the sweet-chestnuts cease to thrive; 1000 feet farther, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4680 feet; and the spruce-fir at the height of 5900 feet, beyond which no tree appears. The rhododendron then covers immense tracts to the height of 7800 feet; and the herbaceous willow creeps 200 or 300 feet higher, accompanied by a few saxifrages, gentians, and grasses; while lichens and mosses struggle up to the imperishable barrier of eternal snow." The accompanying sketch exhibits, in general terms, the order of these ascending zones of vegetation, from the sea-level at the equator to the limit of perpetual snow.

266. Besides the great governing conditions of temperature, as dependent on latitude and altitude, there are others arising from light, slope, nature of soil, moisture, &c., which, though less general, are nevertheless equally imperative. The southern slopes of a mountain-range exposed to the full influence of the sun's rays exhibit not only a greater profusion of foliage and blossom, but a greater variety of species than is to be found on the northern and darker side. Even the southern side of a tree will make a larger amount of annual growth, and present a greater exuberance of flower

and fruit than the northern; and so unfailing is the continuity of nature, that this effect of sunshine is as well marked on the fossil trunks of the Carboniferous and Jurassic epochs as on the concentric layers of the modern *flora*.



Hypsometrical Zones of Vegetation.

Again, the influence of soil is equally observable; hence we seek in vain on the clayey moorland for the species that form the rich and verdant carpeting of the calcareous district; or on the thirsty sand-dunes by the sea-shore for the flora that flourishes so freely on the alluvial meadow. Farther, some plants are truly littoral, and thrive best (like the mangrove and cocoa-palm) within the influence of the sea-spray; while others become stunted and diseased if exposed, even for a season, to the breath of the sea-breeze. The effect of moisture on the distribution of vegetation is direct and perceptible, arid tracts being comparatively barren, while humid regions, and especially humid and warm ones, are noted for their luxuriance. Even in tropical countries, like South America, the dry season is one of torpidity, and corresponds to the winter of temperate zones — vegetation being dormant till the rainy season returns and once more renews its growth and foliage. It is owing to this influence of moisture that botanists distinguish between rainy and rainless regions, and between zones of summer rains, winter rains, and rains at all seasons —each zone being stamped by its own vegetable aspects.

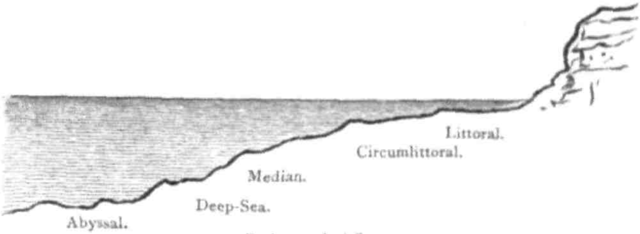
Plant Distribution—Oceanic.

267. As plants have a fixed and natural distribution on land, so also they have a similar distribution, horizontal and vertical, in the waters; though, in consequence of the greater uniformity of temperature, the marine areas are less marked and decided. Thus:—

Horizontally, the ocean has been divided into certain botanical provinces, of which our limits will merely permit the enumeration: 1. The Northern Ocean, from the pole to the 60th parallel; 2. The North Atlantic, between the 60th and 40th parallels—the great headquarters of *Fucus* proper; 3. The Mediterranean—a sub-region of the warmer-temperate zone of the Atlantic, lying between the 40th and 23d parallels; 4. The tropical Atlantic, in which *Sargassum* abounds (Sargasso Sea, par. 160); 5. The Antarctic American regions, from Chili to Cape Horn, and the whole circumpolar ocean south of the 50th degree of S. latitude; 6. The Australian and New Zealand; 7. The Indian Ocean and Red Sea; 8. The Japan and China Seas, besides certain less decided provinces in the Pacific.

Vertically, or *bathymetrically* as it is termed when treating of the ocean (Gr. *bathys*, deep; *metron*, a measure), light, depth, and nature of sea-bed seem to be the prime regulators of aquatic vegetation. In the limited areas of streams and fresh-water lakes the order of arrangement is less perceptible, but in the seas each deepening off-shore zone is characterised by its own peculiar forms. Thus, in the British seas naturalists speak of a littoral, laminarian, coralline, and coral zone; and in the ocean generally, of a littoral, circum-littoral, median, deep-sea, and abyssal zone. The nature of these bathymetrical subdivisions will be best understood by referring to our own shores, where the *littoral* is that which lies between high and low water mark, and is characterised by such plants as the bladder-wrack, dulse, and carigeen; the *laminarian*, that which commences at low-water mark, and extends to a depth of from 40 to 60 feet, and marked, as its name implies, by the broad waving tangle (*laminaria*) and larger algæ; the *coralline*, that which extends from 90 to about 300 feet in depth, and where corallines luxuriate, and the common sea-weeds disappear;

and the *coral zone*, which lies between 300 and 600 feet, and is the region of the calcareous and stronger corals. In the deeper abysses of the ocean, diatoms (microscopic vegetable



Bathymetrical Zones.

forms) alone occur. As the corallines increase the true sea-weeds disappear, ordinary algæ scarcely existing beyond a depth of 300 feet.

Plant Distribution—Regions, &c.

268. Admitting, however, in the fullest degree, the influence of heat, light, moisture, and the like, in the distribution of vegetable life, there still lies over and above them a primal arrangement, by which certain forms are naturally restricted to certain areas. This arrangement, which is seemingly not dependent on climate (for the plants thrive equally well when transferred to other areas), imparts a certain physiognomy to these regions; and thus botanists, entering more minutely into the geographical aspect of their science, subdivide the earth into *regions* and *provinces* according to their prevalent floras. The learner will readily perceive their bearings when he considers—*first*, that some forms, like the tea-plant and camellia, are peculiar to eastern Asia: some, like the eucalypti and casuarinæ, to Australia; others, like the magnolia, to the southern latitudes of North America,—and so on: while, *second*, that every tribe of plants has a special aspect or physiognomy, and where such tribes prevail, that physiognomy will be imparted to the landscape. Wherever, therefore, certain orders are peculiar, and a certain number of genera and species prevail, this constitutes a botanical "region," such as the region of

saxifrages and mosses, the region of magnolias, the region of camellias and teas, region of palms, and so on, making in all some twenty-four regions, into which the earth's surface has been botanically divided. In like manner with aspect or "physiognomy," as the Palm form, the Banana form, the Mimosa form, Cactus form, Heath form, Grassy form, Willow form, &c.—there being in all twenty-two such forms, which are readily distinguished even by the eye of the unbotanical observer. In the same way it is not unusual to divide the Old and the New World into agricultural zones, in something like the following order, from the tropics to the northern limit of profitable culture:—

1. Zone of rice and maize.
2. ,, maize and wheat.
3. ,, wheat, rye, buckwheat, peas, and beans.
4. ,, beans, barley, oats, and potato.

Having regard to the geographical distribution of the various forms of plants upon the earth's surface, Dr Bentham has proposed to arrange existing plants into three main geographical groups—viz., the "Northern Flora," the "Southern Flora," and the "Tropical Flora." The *Northern Flora* includes three geographical types or sub-floras—the Arctic-alpine, the Temperate, and the Mediterranean; the *Southern Flora* is divided into Antarctic-alpine, Australian, Andine, Mexican, and South African; while the *Tropical Flora* is made up of the three sub-floras proper to Indo-Malaya, Mid-Africa, and South America. (See also par. 274.)

269. Such, in general terms, is the distribution of plants over the surface of the globe. Though many families have a very narrow range, and naturally are never found beyond it, yet others, having greater facilities for the dispersion of their seeds, and being, moreover, of a more elastic constitution, have a tendency to increase their area, and this often at the expense of other families that are destroyed by their presence. Others, again, possessing this greater adaptability, are transferred for their utility or ornament from region to region, and are now found *acclimatised* and growing luxuriantly in many countries to which they naturally would never have found their way. In general, however, the great natural laws of distribution are supreme, and the majority of plants attain their perfection only in the stations to which

they originally belong. In densely-peopled and cultivated countries man is ever destroying, transferring, and acclimatising; but, knowing the limit to which this power can be profitably exercised, he will cease to rear in one region what can be more abundantly and cheaply procured from another. It is thus that a knowledge of the geographical distribution of plants, and the laws on which that distribution depends, becomes a subject not only of scientific interest, but of true economic importance.

Animal Distribution—Terrestrial.

270. Being influenced by climate, food, and other external conditions, animals, like plants, are necessarily less or more restricted to certain geographical regions. Endowed with greater powers of dispersion and locomotion, their limits are, perhaps, less precise than those of plants; but in the main there is a similar horizontal and vertical arrangement of animal forms—from the equator to the poles, and from the sea-level to the loftiest heights of land, or to the greatest depths of ocean. The *fauna* of the tropics, taken in general terms, is more exuberant in kind, in size, strength, and beauty, than that of the temperate zones; and this, again, more abundant than that of the arctic and antarctic regions. The more luxuriant and sheltered lowlands are peopled by races differing from those that inhabit the mountain-slopes, and those that affect the mountain-sides are distinct from those that find subsistence among the higher and colder elevations. In like manner, the creatures that throng the shallow shore are specifically different from those that are scattered through the deeper ocean.

271. In this way terrestrial animals may be arranged into a tropical, a temperate, and an arctic fauna—each shading to a certain extent into the other, but still, in the main, characterised by genera and species that do not naturally occur in the other sections. Thus,—

The *Tropics* are the great headquarters of the apes and monkeys; of the lion, tiger, panther, and larger carnivora; of the giraffe and zebra; the elephant, rhinoceros, hippopotamus, and tapir; the crocodile, turtle, boa, and larger reptiles; the ostrich, flamingo, peacock, parrots, humming-birds, and generally of birds remarkable for their brilliant

orders. At great depths, however, life decreases in numerical abundance, and at extreme depths is comparatively insignificant. In a cast 91 miles north of St Thomas (West Indies), and at a depth of 3875 fathoms, Sir W. Thomson (Challenger expedition) found only a few small foraminifera; and remarks that "this dredging only confirmed our previous conviction that very extreme depths, while not inconsistent with the existence of animal life, are not favourable to its development." Much, however, depends on the nature of the sea-bed; and more extensive soundings are needed to enable us to arrive at general and satisfactory conclusions.

Localisation and Representation of Species.

274. It must ever be borne in mind, however, that although external conditions have most distinctly a paramount influence in regulating the range of living beings, there is, over and above, an aboriginal dispersion the origin of which is one of the most difficult problems for which science has yet to furnish a satisfactory solution. Why, for example, should the kangaroo be restricted to Australia, and the hippopotamus and giraffe to Africa; the camel to the Old World, and the llama to the New? Why, on the other hand, do we find distant regions, having nearly the same climatic conditions, peopled—not by forms precisely identical, as might have been expected—but by representative species; that is, by species zoologically distinct but representing each other in the economy of nature and fulfilling corresponding functions? Thus the lion and tiger of the Old World are represented by the puma and jaguar of the New; the ostrich of Africa by the rhea of South America and the emu of Australia; the crocodile of the Nile by the gavial of the Ganges and the alligator of the Amazon. Nor are these strange phenomena peculiar to the groups of living beings which now inhabit these different areas; but they were to the full as strikingly characteristic of their predecessors,—the sub-fossil faunas of Asia, America, and Australia differing from each other in the same direction and to the same extent, and showing precisely the same strange correspondences as do their faunas of the present day. How far these peculiarities in the animal populations of widely

separated areas are dependent upon the inevitable changes brought about in the lapse of ages by the ever varying distribution of sea and land, is not yet fully determined. But natural causes such as these must have greatly affected the wellbeing of the species composing these faunas, by disturbing their local conditions of food and shelter, by destroying their relative immunity from enemies, and the like; and must have thus brought about the rapid dispersion of some species, and caused others to lose their ground, to diminish in numbers, or even, finally, to disappear altogether. Relying upon these facts, naturalists have found it possible of late years to parcel out the land surface of the globe into six Zoological Regions, each peopled by a fauna largely peculiar to itself, but possessing a certain proportion of species in common with its neighbours. These regions, which have only subordinate relations to climate, shade into each other along their lines of contact, as do the zones already described, and, like these, present peculiarities of vegetable life almost as important in degree as those of the animal world. These regions, first indicated by Mr Sclater, and recently more exactly defined by Mr Wallace, our greatest authority in Geographical Zoology, possess the following characteristics: (1.) *The Palæarctic or Northern Old World Region* includes the whole of Europe, all temperate Asia lying north of the latitude of the southern slopes of the Himalaya mountains, and Africa north of the Great Desert. This region is marked by the prevalence of such animals as bears, deer, horses, rabbits, and wild goats; eagles, hawks, jays, and sparrows; and to its limits are confined almost all the known species of goats and sheep, of moles and dormice, the majority of the robins, magpies, and finches, and the whole of the group of the pheasants. (2.) *The Ethiopian or African Region* embraces the whole of Africa south of the Tropic of Cancer, the large island of Madagascar and its dependencies, and the southern portion of Arabia. Its fauna is marked by the absence of northern forms, as the bear, deer, ox, and camel, and by the presence of a wonderful collection of large and peculiar quadrupeds found nowhere else—the gorilla, the chimpanzee, the baboon, the lion, the rhinoceros, the hippopotamus, and the giraffe; together with such remarkable birds as the ostrich, the guinea-fowl, and the ibis and flamingo. (3.) *The Oriental or*

ZOOLOGICAL REGIONS.

Indian Region comprises, generally speaking, the countries of Hindostan and Further India, and the East Indian islands, &c., as far as the Strait of Macassar. In this region only do we find the orang-outang, the tiger, the honey-bear, the civet, the flying lemurs, and the flying squirrels; the magnificent peacock, the argus pheasant, the laughing-thrushes, and the curious little tailor-birds. (4.) *The Australian Region* includes Australia, New Zealand, Polynesia, and those Malayan islands lying east of the Strait of Macassar. This region is pre-eminently distinguished by the absence of the higher mammalia of other areas, their position being occupied by marsupial or pouched animals, such as the kangaroo proper, the wombat, the tree-kangaroo, and the kangaroo-rat. The bird-life, however, is abundant and varied, and is rich in handsome and peculiar forms, such as the beautiful birds of paradise, the crimson lories, the lyre-birds, and the strange-looking emus and cassowaries. (5.) *The Nearctic or North American Region* comprises the whole of the continent and islands of North America lying to the north of the Tropic of Cancer. Although agreeing almost exactly with the Palæarctic region as regards temperature, it differs from it most materially in the composition of its fauna, having none of the hedgehogs, dormice, pigs, or sheep of the Old World; but showing instead, such peculiar animals as the skunk, the racoon, the opossum, and the prairie-dog. The thrushes, wrens, and finches of Europe are represented by new families of birds; while the mocking-birds, the blue jays, and a host of others, are wholly peculiar, as also are the rattlesnakes and most of the lizards. (6.) *The Neotropical or South American Region* includes all America and the neighbouring islands lying south of the Tropic of Cancer. This is altogether the most remarkable of all the great zoological divisions of the earth, both as regards its deficiencies in the animal types found in other areas, and in the marvellous abundance and variety of the forms peculiar to itself. The Old World tropical genera of the elephant, rhinoceros, and antelope are here replaced by a large array of genera known nowhere else, such as the sloth, the armadillo, the ant-eater, the llama, the alpaca, chinchilla, &c.; the bloodsucking vampire-bat, and the prehensile-tailed monkeys. The bird-life is equally prolific and varied, as seen in the peculiar toucans, the todies, the macaws, the curassows,

and above four hundred species of humming-birds. These geographical regions answer equally well for the *Vegetable* world. We find each to be characterised by an assemblage of plants peculiarly its own. The region formed by the temperate areas of the Old World is the natural home of the larch, the beech, the ash, the oak, the elm, the walnut, and the chestnut among trees; and of the apple and pear, the cranberry, the strawberry, the currant, and the orange among fruits. The African region south of the Sahara nourishes the enormous baobab, the oil-palm, and the tamarind; and, farther south, crowds of beautiful flowering heaths, aloes, and pelargoniums. The Indian region is the natural habitat of the ginger-plant, rice, mango, bamboo, cinnamon, and ebony. In the Australian region alone do we meet with the peculiar gum-trees, grass-trees, marsh oaks, and bread-fruit trees. In the central parts of the North American region flourish the hemlock, the Douglas pine, and the gigantic Wellingtonia; and, near its southern limits, the sugar-cane, cotton-plant, maize, and tobacco. Finally, the richly prolific South American region claims as its own the brilliantly flowering cactuses and passion-flowers, the medicinal cinchona, the useful india-rubber and logwood trees, and the ornamental rosewood and mahogany.

275. As in the vegetable world, so also (though to a less extent) in the animal, certain species have a special elasticity of constitution which enables them to subsist under a greater variety of conditions, and naturally, therefore, to enjoy a wider geographical range. Operating upon this principle, and a knowledge of climatology, man has been able to transfer from one region to another a considerable number of animals, either for the purposes of his convenience or luxury. All the domestic animals—horse, ass, ox, sheep, goat, pig, dog, cat, barn-fowl, &c.; many birds, prized for their beauty or song; and rats, mice, insects, and other creatures considered as "pests and vermin," have accompanied him over the habitable globe. His efforts in this respect—extirpating, transferring, and acclimatising—have been incessant; and thus creatures naturally of widely distant habitats have been, and are still being, brought together into one common area. In this way the domestic animals of the Old World have been transferred to the New, where they were unknown at the time of its discovery by

Columbus; some of the New World fauna transferred to the Old; and not only the domestic animals, but the birds, fish, and even shell-fish of Europe transported to Australasia, where, within little more than a century, their genera were generally unrepresented. But, as in the vegetable world, so in the animal, there is a limit to this system of transference; and man best studies his own interest and the comfort of the lower animals, by fostering them mainly within their own native habitats, and sharing in their larger produce through the more profitable method of commerce and exchange.

Interdependence of Plants and Animals.

276. As plants and animals are alike dependent on external conditions—air, heat, light, moisture, and food-supply—so both are, to a certain extent, dependent on one another. Both, for example, are dependent on the atmosphere, yet the oxygen which the plant exhales is inhaled by the animal, and the carbonic acid exhaled by the animal is decomposed and partly assimilated by the plant. The plant, rooted in the soil, and casting abroad its leaves and branches in the atmosphere, though seemingly deriving the main elements of its growth from inorganic sources, is nevertheless stimulated into life and exuberance by the presence of organic decay, and many of the lower fungus-growths are found only where such decomposing matter is present. Herbivorous animals, as is well known, subsist directly upon plants, while the carnivorous prey upon the plant-feeders, and are thus also ultimately dependent on the vegetable world for their subsistence. Wherever vegetable life is varied and luxuriant, there animal life is marked by a corresponding variety; hence the specific exuberance of the tropics compared with that of the colder latitudes. And yet this generalisation requires cautious application. Excess of vegetation is not always accompanied by a gigantic fauna; nor does a diminutive fauna at all times result from the growth of a scanty flora. The Cape district of Africa is a noted example of the former condition; the valley of the Amazon is a marked example of the latter. Beyond the tropics, where winter periodically suspends the life of forests and meadows, the vegetable-feeders hibernate

or migrate; while the animal-feeders, in turn, either migrate or betake themselves to the same seasonal repose. By the extirpation of certain plants, certain mammals, birds, and insects may be removed from a district; while, on the introduction of some new exotic, animals hitherto unknown in that locality usually make their appearance. The law of circulation and interdependence is complete, and no portion of the circle could be removed without a corresponding change in the characters of the vegetable and animal kingdoms.

277. Again, though most plants have the inherent power of dispersing their own seeds, and are aided in this by winds and water-currents, yet many depend upon birds and mammals for their wider dispersion and increase, just as many depend upon insects for the fertilisation of their flowers. This wider dispersion creates a new source of subsistence for the animals that feed upon them, and thus the increased area of the one supplies a wider range to the other. Further, as some animals are fitted by their organisation for an arboreal existence, some for life on the grassy plain, and others for the shrubby thicket, the destruction of the tree, the planting of the plain, or the clearing of the thicket would necessarily involve the destruction of these special organisations. Still further, as some creatures are specially fitted to live on fruits, some on leaves, and others on roots, the disappearance of these specific supplies would necessarily be followed by the annihilation of the consumers. It is in this manner that plants and animals become co-dependent portions of one great vital plan, and that geographers, aware of these relations, can more intelligibly depict the aspects of nature by associating every fauna with its own appropriate and distinctive flora.

RECAPITULATION.

278. In the preceding chapter attention has been directed to the vital aspects of the globe—that is, to its vegetable and animal life, and their distribution over the land and through the waters. Leaving the nature and origin of Life to the Biologist, we have shown that plants and animals

are dependent for their continuance on the external conditions by which they are surrounded, and that any change in these conditions would materially affect, if not destroy, their existence. For this reason, plants and animals have a definite distribution over the globe; heat, light, and moisture being the great regulators of the one—climate and food the governing conditions of the other. In this way vital variety and exuberance culminate within the tropics, and decline as we proceed towards either pole—declining also in an analogous manner as we ascend from the level of the sea into the higher elevations of mountains. Each zone or belt of the earth has thus its own special flora and fauna—that is, is characterised by genera and species not naturally occurring in other regions. As marked variations occur within narrower limits than the torrid, temperate, and frigid zones, botanists subdivide the earth's surface into equatorial, tropical, sub-tropical, warmer-temperate, colder-temperate, sub-arctic, arctic, and polar belts; and these, as might be expected, correspond with lines of temperature rather than with parallels of latitude. As on the land, so also in the waters, each zone of depth, from the shore seaward, has its characteristic forms, littoral, laminarian, coralline, and coral; and even the extreme abysses of the ocean have their forms of life.

279. Beyond these main horizontal and vertical arrangements of life, there is also an aboriginal dispersion of certain races over certain areas which science cannot yet account for; hence the division of the earth's surface into botanical and zoological "regions" and "provinces," each subdivision being characterised by its own typical forms. These provinces form the special study of the botanist and zoologist; and the question how far the plants and animals of one region can be profitably transferred to another, becomes one of prime economical importance. Understanding the geographical conditions under which plants and animals naturally occur, and knowing, moreover, the intimate in-

terdependence of the vegetable and animal kingdoms, man, in his own migrations over the globe, will be better able to determine what to cultivate and what to extirpate, what to attempt acclimatising and what to continue in their own native habitats. Understanding, moreover, the relations that subsist between fauna and flora, he will, as a geographer, be better enabled to draw that intelligible picture of external aspects which it is the grand province of his science to depict.

XIII.

ETHNOLOGY—RACES AND VARIETIES OF MAN.

Man as affected by External Conditions.

280. MAN, in whatever stage of civilisation he may appear, is always less or more influenced by the geographical conditions of the region he occupies. Unlike the lower animals, which either simply flourish under or succumb to these conditions, Man may struggle against and so far modify them; but still, to a great extent, his thoughts and actions, his industrial pursuits, his social polity, and religious beliefs, are all affected by the physical circumstances of his position. In savage life this influence is direct and perceptible; hence the difference between the semi-aquatic Esquimaux and the hunting Red Indian, though inhabiting the same continent; between the stationary vegetable-feeding islanders of the sunny Pacific, and the wandering omnivorous tribes of the scrubby plains of Australia. Even where civilisation has made some progress, it is these conditions that still mainly determine man's habits and pursuits—rendering the inhabitants of the grassy steppe nomads and herdsmen, the indwellers of the river-plain tillers of the ground and growers of grain, and the men of the sea-coast traders and adventurers. And higher still, where populations have been long settled and civilisation has assumed its most advanced aspects, climate, scenery, natural products, facilities for intercommunication and exchange, are ever exercising their influence—rendering one nation wealthy and independent, another bold and enterprising, and a third, it may be, isolated and stationary. Nor is it man's

mere material nature that is thus affected: his religious sentiments, his poetic feelings, his love of liberty, his social government, are all less or more tinctured by the nature of his geographical surroundings.

281. That such is the case, the most cursory glance at the different nationalities of the world will readily convince us; and though the inherent qualities of Race, for reasons we cannot now discover, may differ very widely, still over and above these qualities external conditions exert a direct and perceptible modifying influence. The white men of Europe may differ physically and intellectually from the black tribes of Africa and the red races of North America; but it may be fairly questioned whether the former would have ever exhibited their present activity and progress had it not been for the greater varieties of surface, climate, and general physical conditions that Europe, as a continent, enjoys. There can be no doubt that the moderate climate of Britain is more favourable to bodily and mental vigour than the relaxing temperature of the tropics; and that the slight seasonable difference between our spring, summer, autumn, and winter, induces habits of continuous exertion and industry unknown in countries subjected to excessive summer's heat and winter's cold. But for our insular situation, our countrymen would never have been the traders and adventurers they have become; and but for our natural supplies of coal, iron, and other metals, the mechanical and manufacturing character that now stamps the British nation would have been unattainable and impossible. So much does the general character of a people depend upon the physical conditions of the country they inhabit!

282. Even in their minor peculiarities, the different nations of the same great race are similarly affected by external conditions; hence the obvious distinctions existing between the livelier and more versatile nations of southern Europe and the graver inhabitants of the north—between the bold and independent mountaineers of Switzerland, Scotland, and Scandinavia, and the tamer occupiers of the central and eastern European plain. The language of everyday life is full of these distinctions, and this long before science had attempted their explanation. Thus we speak of the "dry, clear, exhilarating air" of one district, and the "damp, cloudy, and depressing atmosphere"

of another; of the "dreary monotony" of one region, and the "charming variety" of another; of the "awe-inspiring gloom" of the forest, and the "cheerful hues" of the open landscape. Indeed it is to the influence of situation that we are in a great measure to look for national peculiarities—these peculiarities diminishing the more that nations extend their range of intercommunication, and the less they are restricted to their own narrow boundaries.

Characteristics and Distribution of Races.

283. Whatever the influence of external conditions in modifying the characteristics of race, we find Man distributed at present over almost every region of the globe—wandering in savage freedom under the tropics, flourishing in busy communities within the temperate zones, and struggling in diminished numbers against the inclemencies of the polar regions. Within the tropics he is chiefly a vegetable feeder; in the temperate zones he adopts a mixed vegetable and animal diet; while within the polar circle his diet is exclusively animal. But while in this respect he obeys, like plants and animals, the zonal arrangements of the world, unlike them the varieties of his race are distributed according to no law of latitudinal dispersion. As in districts of the same country we find differences of stature, physiognomy, dialect, and habits; so in the various countries of the same continent we find still wider differences in bodily appearance, mental constitution, language, and manners. Notwithstanding these well-known distinctions, there is among the inhabitants of certain regions a certain sameness in physical aspect, in colour of skin, in form of head and face, and also in mental disposition, that stamps them as distinct from the inhabitants of other regions; and hence arises the idea of *varieties* or *races* of the human species.

284. Without entering upon the vexed questions of man's origin and antiquity—whether he is a mere development from the lower animals, according to some great natural plan, or an entirely new creation—whether he has been six or sixty thousand years an inhabitant of the earth—and whether the varieties of our race have descended from a single pair, and been since modified by external conditions,

or are the progeny of several independent pairs—it may be stated as the general opinion of naturalists that mankind form, in the zoological scale, a single species of a single genus. But though thus standing unique, and far exalted above other animals by his gifts of reason, moral perception, and religious sentiment, it is necessary and natural to divide mankind into several varieties, according to their more prominent physical features; and Ethnology (Gr. *ethnos*, a race; *logos*, a discourse), extending the subject to minor features, language, and the like, still further subdivides these varieties into groups, tribes, and branches. The consideration of these minor distinctions (which are evidently produced by intermixture of races and the influence of external conditions) belongs more especially to Ethnology; our limits will merely permit a brief allusion to the *five* varieties or races into which the inhabitants of the globe by the German philosopher Blumenbach were arranged about a century since (1781)—a grouping which (though admittedly tentative) has had great effect in systematising our knowledge upon the subject. These are the *Caucasian*, the *Mongolian*, the *American*, the *Ethiopian*, and the *Malay*; each being characterised by some peculiarity in colour of skin, eyes, nature of hair (curled, lank, woolly, frizzled), shape of skull, form of face, and general physiognomy. Of these characteristics, colour of skin is one of the most obvious, and though varying in shade even in the same race, is yet employed in everyday language as a main mark of distinction—the Caucasian being the *white*, the Mongolian the *yellow*, the American the *red*, the Ethiopian the *black*, and the Malay the *brown*. The distribution and more obvious characteristics of these respective races we epitomise from Blumenbach and other ethnologists:—

285. The *Caucasian* variety is dispersed over Turkey, Arabia, Persia, part of Tartary, Afghanistan, and Hindostan, in Asia; over Egypt, Abyssinia, and the Mediterranean seaboard, in Africa; and over almost the whole of Europe—the Turks proper, the Magyars, Finns, and Laplanders, being of Mongolian origin. Within the last three centuries the race has spread from Europe over large areas of North and South America, South Africa, Australia, and New Zealand (see Ethnographic Map in Atlas); and wherever it has planted itself becomes the dominating

power. This variety takes its name from the Caucasian mountain-range that stretches between the Caspian and the Black Sea, because tradition points to that region as the place of its origin; and it is also known by the term *Indo-European*, from its spreading over India and Europe from the Ganges to the further shores of Iceland. The more important branches are the Hindoo, Persian, Arab, Circassian, Slavonic, Teutonic, and Celtic, with their various mixtures and alliances, which now constitute the nationalities of Southern Asia and Europe.

The distinguishing characteristics of these Indo-Europeans are—a light-coloured skin, varying from fair to tawny or swarthy; red cheeks; copious, soft, flowing hair, generally curled or waving; ample beard; small, oval, and straight face, with features distinct; expanded forehead; large and elevated cranium; narrow nose; and small mouth. In stature the Caucasian is taller than any of the other varieties; of erect gait; with rounded, well-proportioned limbs; moderately small extremities; and light elastic step. The *White* race (for by this designation it is generally distinguished) has given birth to the most civilised nations of ancient and modern times; and has hitherto exhibited the intellectual and moral powers of human nature in their highest degree. Wherever the white man has established himself, the other races disappear before him. His proper field of development, however, seems to be the temperate zones in either hemisphere; for beyond these, as far as experience has yet shown, he degenerates physically and intellectually, and loses the higher characteristics of his race.

286. The *Mongolian* variety is spread, as the name implies, over the central and northern regions of Asia, China, Japan, Burmah, Siam, and Cochin China; and includes, moreover, the scattered inhabitants of the Arctic seaboard, both in the Old and the New World continents. It embraces the Mongols, Turks, Tibetans, Chinese, Indo-Chinese, Japanese, Kamtchatdales, Tungusians, Koriaks, and Samoiedes, in Asia; the Turks, Finns, and Lapps, in Europe; and the Esquimaux of the North American Arctic regions. In the Mongolian, the skin is olive-yellow; the hair thin, coarse, and straight; little or no beard; head or cranium somewhat square-shaped; forehead rather low; face broad

and flattened, with confluent features; high cheek-bones; eyes rather sunk, and obliquely directed towards the nose; wide and small nose; and thick lips. In stature the Mongolian is below the Indo-European; but in the true Tartar, Turk, and Chinese the frame is broad, square-set, and robust, with high shoulders, and short and strong neck. In intellectual and moral capacity the various branches of the race differ very widely; but on the whole they are inferior, less energetic, and more stationary in their civilisation, than the Caucasian variety. Their highest attainments appear in the Chinese and Japanese; the Turks and Magyars having been so long amalgamated with Europeans as to assume a Western rather than an Oriental phase of civilisation.

287. Under the *American* variety, ethnologists comprise all the aboriginal races which peopled the New World prior to its discovery by Columbus in 1492. These are the Chippewyans, Sioux, Pawnees, Cherokees, and other tribes in North America; and the Caribs, Solimoes, Guaranis, Araucanians, Patagonians, and Fuegians, in South America. In this race the skin is reddish or copper-coloured (hence the familiar designation of Red Indian); the hair is black, coarse, and lank; beard scanty; skull somewhat similar to the Mongolian, but narrower, and not so square; forehead low and retreating; cheek-bones prominent, but more rounded than those of the Mongol; eyes sunk, and somewhat raised at their outer angle; nose and other features rather prominent. In stature the North American Indian is rather tall; spare and lithe in body; and, as a hunter, acute in his senses, and remarkable for his endurance of fatigue and insensibility to pain. In South America the race greatly degenerates; the Guaranis, the Fuegians, and other tribes being amongst the most degraded of savages, their wretched appearance being in many instances aggravated by artificial distortion of the head and facial features. In intellectual and moral qualities the American Indians resemble in many respects the Mongolians. Like the Mongols, they have remained stationary, but at a much lower point of civilisation, if we except the ancient inhabitants of Mexico and Peru—table-lands which seem to have presented more favourable conditions for permanent occupation and civilisation. In North America the race is

1. Caucasian; 2. Mongolian; 3. Ethiopian; 4. Malay; 5. American.

rapidly disappearing before the white settlers; in South America, less fitted for the White, the inferior and more sparsely scattered tribes have been little interfered with.

288. The *Ethiopian* race, in one or other of its branches, inhabits the whole of Africa, with the exception of Egypt, Abyssinia, and Nubia on the east, Tunis, Tripoli, and Morocco on the north, and Cape Colony on the south. It embraces Hottentots, Bushmen, Kaffirs, Negroes, Gallas, Tibboos, Mandingoes, and other tribes, differing widely among themselves in physical and mental aptitude, but all, from time immemorial, remaining in a barbarous or but very partially civilised state. In this variety, which derives its name from the Ethiopia of the ancients, the skin is black (hence the familiar designation, Negro—Lat. *niger*, black); the hair short, black, and woolly; skull compressed on the sides, and elongated towards the front; forehead low, narrow, and slanting; cheek-bones very prominent; nose broad and flat; jaws projecting so as to make the upper front teeth oblique; lips, especially the upper ones, very thick. In stature there are great differences among the different branches of the race—some, like the Kaffir, being of average size, and fairly formed; others, like the true Negro, also of average size, but ungainly in form and limb, with large flat feet and hands, and shuffling, awkward gait; and some again, like the Hottentot and Bushman, of stunted stature, and with slender, ill-formed limbs. Intellectually, the Black race has ever remained in a rude and barbarous state; hence the subjection of one branch to another branch among themselves; and hence also their enslavement, from time immemorial, by the white variety. This is not the place to enter upon the question, how far the negro is capable of attaining the higher phases of civilisation; but the fact remains, that neither of himself nor in any of his admixtures with other races, has he shown much aptitude for intellectual or social advancement.

289. The *Malay* race (so called from the Malayan peninsula), includes the widely scattered and chiefly insular inhabitants of Malaysia, Australasia, and Polynesia. The population of these widely spread districts differ, as might be expected, very widely from each other—those of Malaysia and Polynesia being of a brown or lighter colour, and somewhat resembling the Mongolians; while those of New

Guinea and Australia (the Papuan negroes, as they are termed) are of a dark colour, and more closely approximated to the negro type. Intellectually, also, there is a similar difference, there being little in common between the Malay of the Indian Archipelago and the savage inhabitant of New Guinea; between the stunted and miserable native of Australia, and the daring, apt, and clever inhabitant of New Zealand. Taken, however, as described by ethnologists, the skin of the Malay varies from a light tawny to a deep brown; hair black, crisp, and somewhat inclined to curl in the true Malay, and tufted and frizzled in the Papuan; head rather narrow; bones of the face large and prominent; nose full and broad towards the lips. In civilisation the Malay race has hitherto made little advancement. In the Indian Archipelago, it has, like the Mongolian, long remained stationary; in Polynesia, some progress appears under tutelage of the white, though the areas are too widely separated ever to be of much importance; in New Zealand it seems reluctant to amalgamate with the new settlers; while in Australia it is rapidly dying out before the encroachment of the European immigrant.

290. Blumenbach's arrangement has been superseded in great part by other and more elaborate schemes of classification; but none have yet been propounded which have met with such general acceptance. The most recent and complete of those schemes is that of Professor Huxley, who distinguishes four chief races of mankind, typified by (*a*) the Australian, (*b*) the Negro, (*c*) the Mongol, and (*d*) the European or White man. The *Australian-like* race includes the Australian aborigines and the coolies of Southern India. The *Negro-like* race embraces the Negroes proper, and also the Bushmen and the negro-like inhabitants of some of the East Indian Islands. The *Mongolian* race not only includes the Mongols proper, but also the Malays, Polynesians, and American Indians. The *White* race is supposed to be composed of two main varieties—the *Pale Whites* and the *Dark Whites;* the former including the people inhabiting the inland region lying between Britain and India—and the latter the Celts, Spaniards, Greeks, and Arabs. But retaining Blumenbach's scheme as an aid to the *general* arrangement and consideration of mankind, it must be remembered that there are not only admixtures among

conterminous races (Caucasian and Mongol, Mongol and Malay, Mongol and American), but admixtures also between immigrant and native races (Brazilians, Peruvians, Mexicans, &c.), which render sharp lines of demarcation impossible, and unnecessary as impossible. The consideration of these *minutiæ* belongs more especially to Ethnography and Philology, by which not only shades of colour, types of skull, facial angles, and the like, are taken into account, but dialects of language, mental peculiarity, and forms of government, are all considered in tracing the dispersion, affinities, and history of the human race. Such considerations lie beyond the scope of our outline, and the learner may consider as sufficient for his purpose the *five* great varieties above enumerated, or even their abridgment into *three* (Caucasian, Mongolian, and Ethiopian—reckoning the American as a sub-variety of the Mongol, and the Malay a sub-variety partly of the Mongol and partly of the Negro), as all that is warranted or required at this stage of his progress.

Conditions of Civilisation and Progress.

291. Such is the usual subdivision of mankind into varieties or races, and such the existing distribution of these races over the surface of the globe. The subdivisions may to some extent be arbitrary; but as there are actual differences of colour, form of head, facial expression, and the like, and as these physical features are accompanied by strongly marked differences in mental constitution, the distinctions in the main must be founded on nature. As to the prehistoric distribution of man, neither archæology nor geology, in the absence of reliable remains, can arrive at any certain conclusion. Within historical time, however, the various races, while peopling most densely the regions they now occupy, have ever been less or more encroaching on each other's domain—the inferior giving way to the superior and more civilised. The Ethiopian, in its numerous tribes and branches, has remained stationary in Africa. The Malay, chiefly an insular race, has spread itself, in one or other of its branches, over the islands of the Southern Ocean and Pacific. The Mongolian, while claiming Cen-

tral and Eastern Asia as its headquarters, has spread partially into Europe, and largely along the entire seaboard of the Arctic Ocean. The white man, on the other hand, has partly repelled the Mongol, and, after spreading wave after wave over Western Asia, Northern Africa, and the whole of Europe, has within the last three centuries taken possession of the greater portion of North America (United States, Canada, Mexico, California, &c.); of part of South America (Brazil, Guiana, Peru, &c.); of South Africa; and of Southern Australia and New Zealand; while his influence is felt, less or more, in every region of the globe.

292. Wherever the means of subsistence can be obtained, there man will establish himself and increase in numbers—his increase being mainly regulated by the facility or difficulty of obtaining supplies. Where he can raise more than his own wants require (and this will depend very much on his knowledge of nature's laws and operations), or where he enjoys products not possessed by other localities, this surplus and these products form subjects of barter and exchange, and thus he acquires wealth and the power to command luxuries. Raised above the mere physical struggle for existence, the higher faculties of his mind—imagination, invention, reflection, moral perception, and religious sentiment—begin to develop themselves, and man passes from the domain of savagery into the categories of civilisation. To trace the course of civilisation lies beyond the scope of our subject; but it is evident, from what has been repeatedly stated, that its advancement (laying altogether aside the consideration of Race) depends, in a great measure, on the geographical or physical conditions by which it is affected. Wherever there exists a favourable climate, the means of subsistence, and opportunities of interchange and barter—in other words, wherever there are the objects and means of successful industry—there civilisation will manifest itself; and just as equitable laws, protection of property, freedom of action, and liberty of opinion are enjoyed, so civilisation will advance in a corresponding ratio. In absence of these adjuncts it has passed, and may yet pass, from nation to nation; but in the aggregate its maintenance from epoch to epoch has been secure—its progress seems illimitable.

RECAPITULATION.

293. In the preceding chapter attention has been briefly directed to the varieties and distribution of the human species—Ethnology or Ethnography being the science which treats of these distinctions. It has been shown that man, though possessing a greater elasticity of constitution than most of the lower animals, and capable of enduring under almost every climate, is still, to a great extent, influenced by the external conditions by which he is surrounded, both in his physical and mental relations. Whether owing to these influences, or arising from aboriginal differences which science cannot explain, Man now appears in several *varieties* or *races*—each occupying well-marked territories on the globe, and distinguished by peculiarities of colour, form of head, facial expression, and other *physical* features, as well as by equally obvious *intellectual* and *social* qualities. According to Blumenbach's scheme these varieties are the *Caucasian* or *white*, the *Mongolian* or *yellow*, the *American* or *red*, the *Ethiopian* or *black*, and the *Malay* or *brown*—each embracing a great number of tribes, branches, and nationalities, differing in language, social polity, and other peculiarities. The Caucasians, or Indo-Europeans, inhabit the south-western section of Asia, the northern belt of Africa, and nearly the whole of Europe, and have, in modern times, extended their dominions to large areas of North and South America, South Africa, South Australia, and New Zealand. The Mongolians, concentrated chiefly in Central and Eastern Asia, have partially penetrated into Eastern Europe, but are most extensively spread in scattered communities along the entire seaboard of the Arctic Ocean. The Malays, having their headquarters in Malay and the Indian Archipelago, are spread, in one or other of their tribes, over Australia, as well as over all the island-groups that stud the bosom of the Pacific. The Ethiopians,

though drafted hither and thither as the slaves of the white man, have been mainly stationary in Africa, the natural home and habitat of their race; while the Americans, or Red Indians, have been equally restricted to the New World continent. As a whole, the Negro and Red Indian have made, and still make, the least progress in civilisation; hence their easier subjection by the higher races, and hence also their rapid disappearance before them. The Malay and Mongolian come next in order; and though some of their sections (Chinese, Japanese, &c.) have arrived at considerable eminence in the industrial arts, yet in both races the essentials of higher progress seem wanting: hence, compared with Europeans, their torpid and stationary aspect.

294. The recent awakening of Japan to the arts and industries of European civilisation forms one of the most wonderful episodes in human history, but it is yet too brief and partial to constitute the basis of any satisfactory deduction. By the White race alone do we find displayed the higher efforts of bodily and mental activity, perseverance and endurance, inventiveness and fertility of resource: hence in ancient times the civilisations of India, Assyria, Palestine, Egypt, Phœnicia, Greece, and Rome; and in modern times those of Western Europe—Austria, Germany, France, and Britain; of the United States and Canada; and, generally, of our colonies, in whatever region of the globe they may happen to be established. The conditions favourable to this civilisation are partly of a geographical or physical nature, and partly intellectual: and wherever the two are fortunately in conjunction, there the progress of the White race is certain, and illimitable as certain.

XIV.

GENERAL REVIEW AND DEDUCTIONS.

295. THE object of Physical Geography being not only to describe the external aspects of nature, but to determine the causes by which these aspects are produced, it has been necessary in the preceding chapters to deal with principles as well as with details. Indeed, in an elementary outline the principles are of more value than the descriptions, the learner being readily enabled to extend the latter by his own readings of voyages and travels, but only intelligibly so when he has mastered the principles upon which the phenomena depend. The aim throughout has been to present our planet as subjected to general laws, believing that when these are understood there will be little difficulty in comprehending their modifications in local and limited areas. Let the learner clearly understand the origin, for example, of winds and rains, of tides and currents, and he will soon find his way to determine the causes that produce their modification in any special locality.

296. In accordance with these views, attention has been directed to the planetary relations of the earth—its figure, motions, dimensions, &c.—as on these depend its light and heat; its alternations of day and night, summer and winter; and, in general terms, all that gives rise to change and diversity in its external conditions. It is, in fact, to its solar relations that the earth owes, if we may so speak, its life and activity, deriving therefrom *directly* its rotation, revolution, heat, light, seasonal differences, and tides; and *indirectly* its winds, waves, and currents, its rains, snows, and frosts—all that produces peculiarity in its climates,

diversity in the distribution of its plants and animals, and change in the geological relations of its rocky exterior. It was necessary, also, to consider the individual structure and composition of the globe, and the geological changes which, under the operation of aqueous, igneous, and meteoric forces, that structure has been and is still undergoing. Seizing upon its present terraqueous aspects (its lands and waters), the more immediate province of our science was to investigate their relative distribution—the disposition, highlands, and lowlands of the one, and the configuration, waves, tides, and currents of the other. Understanding the relations of land and water, and their necessary actions and reactions on each other, attention was next directed to the atmosphere by which both are surrounded, through which the light and heat of the sun are diffused to both, and in which are elaborated the winds, rains, frosts, snows, and other phenomena that constitute the essentials of weather and climate. This all-circling atmosphere is the great bond of union between land and water, between plants and animals, equalising and regulating the heat and moisture of the former, and conveying and supplying the vital gases so indispensable to the life and growth of the latter.

297. The consideration of this earth as revolving through space as part of the solar system, as composed superficially of land and water surrounded by an atmosphere, and as receiving heat, light, and other influences from the great central orb, constitutes what may be termed the *physical* or *inorganic aspect* of geography. On the other hand, the study of the earth as peopled by plants and animals, and inhabited by man, capable of applying the whole to his own social and moral advantage, depends upon its *vital* or *organic features*. The study of the vital world—the distribution of its plants and animals, the causes concerned in that arrangement, and the dependence of the one kingdom on the other, is one of the most attractive themes in geography. Still higher, however, and of more immediate interest, is that which deals with our own race—their physical and mental peculiarities, their dispersion over the globe, and the question how far geographical conditions may influence their social, intellectual, and moral progress.

298. But our science has its practical as well as theoretical importance—its economic as well as its scientific

aspects. A knowledge of the distribution of sea and land—the winds, tides, and currents of the one, and of the highlands, lowlands, and climate of the other—is indispensable to successful navigation, commerce, and agriculture. The duty of determining the earth's mineral, vegetable, and animal products, and how far they can be rendered available for the purposes of everyday life, is not less imperative than the solution of its physical and vital problems. It is of vast importance to know the facts of nature, but it is not less important to learn how to turn them to practical advantage. All knowledge of nature is good of itself, but its value is doubly enhanced when it can be made to minister to the wants of our common humanity. Combining, therefore, its theoretical with its practical bearings, and remembering that every country is characterised by its own natural products, and has consequently something that no other country can supply, Physical Geography has paramount claims alike on the attention of the philosopher, the statesman, the sailor, the farmer, the merchant, and manufacturer.

299. The material wealth of the globe—that is, the products derivable from the mineral, vegetable, and animal kingdoms, and capable of being employed so as to administer to the comforts and luxuries of life—forms the leading theme of economic geography. Every country, in virtue of its geological age and formation, has some special mineral or metal in greater or less abundance; and every region, in virtue of its position and climate, produces vegetables or animals peculiar to its own area. Man's ingenuity is ever on the rack for new inventions in the arts and manufactures; and as all his raw materials are drawn from one or other of the realms of nature, he turns to Physical Geography for indications of the character, abundance, and accessibility of the products that belong to the different countries of the globe. This search produces commerce, commerce brings about communion between the most widely diverse and separated regions, and this communion is the main incentive to civilisation and human progress. In this way Britain draws the raw materials of her manufactures from every accessible portion of the globe, returning thither her manufactured goods, and thereby creating new wants, new activities, higher aspirations, and all, in

fine, that arises from the contact between superior and inferior civilisations.

300. Such, in general terms, is the aim and scope of Physical Geography; but it must be borne in mind that, subjected to the aqueous and igneous forces described in Chapter III., the aspects of the globe are continually undergoing change and modification. These changes may be all but imperceptible even for several generations; but in process of time they become sufficiently apparent, and stamp new features on the external conditions of the globe. The air and water, ever wearing and wasting the rocky surface in one district, and collecting the eroded material in another—the earthquake and volcano, elevating the solid crust in one region and depressing it in another—are ever changing the relative positions of sea and land; and thus the seas and lands of the future must differ from the seas and lands of the present, as those of the present differ from what Geology assures us existed in time past. Every change of the external relations of sea and land implies a corresponding change in the nature and distribution of plants and animals; and here, again, the life of the future must differ from that of the present, as the present differs from that revealed to us by the researches of Geology.

301. *In this way the student of Physical Geography must* regard the earth and all its relations—physical and vital—as in a state of incessant change and progress. The changes may be slight—so slight as to pass unobserved—yet still they are not on that account less real or certain. Bearing these facts in mind, we can more readily comprehend why the rocks (the old sea-sediments) of one region should differ from those of another, why the mountain aspects of the one should differ from those of the other, and why one tract should be low and alluvial, while another is high and rocky —each feature being the product of a certain time and change in the earth's relations. It is also by bearing in mind this great feature of incessant change that we can account for the similarities and differences that exist between the flora and fauna of different regions—regions that may at one time have been continuously connected by land, though now widely separated by expanses of ocean. The plants and animals of Britain, for example, claim kindred with those of Europe, and this through land connections

that existed long before their separation by the Strait of Dover. It is, in fine, by carrying this idea of mutation into all our reasonings, that Physical Geography becomes a more intelligible part of World-history—connecting the past with the present, and bearing the present into the inevitably approaching future.

302. As formerly stated, the chief agents concerned in the modification of the earth are the winds, rains, frosts, and snows of the atmosphere, which are ever loosening and disintegrating the exposed rocky surface; the streams, rivers, waves, tides, and ocean-currents, which are incessantly wearing and wasting and redepositing the eroded materials along the bottom of the sea; and the earthquake and volcano, whose operations are alike incessant in upheaving and depressing the crust—now raising the sea-bed into dry land, and now submerging the dry land beneath the waters. The consideration of these agencies belongs more especially to Geology; but their results bear so directly on the terraqueous surface that they cannot possibly be overlooked by the geographical observer. Some idea of the magnitude of their combined influences may be formed by reflecting on the number of streams and rivers that are ever coursing over the earth's surface—on the extent of coast-line exposed to the action of waves and currents—and on the areas in Iceland, Italy, Central Asia, Indian Archipelago, Philippine, Japan, and Aleutian Islands, Mexico, West Indies, Andes, and the Pacific Islands (see Sketch-map of Volcanoes), that are subjected to earthquake and volcanic disturbance. Notwithstanding these continual operations, their results, for the time being, do not greatly affect the general relations of the earth; and thus Geography is enabled to depict, within appreciable limits, its existing aspects in an intelligible and available form.

303. It is this intelligible account of existing appearances, and the causes concerned in their production, that constitutes the sum and substance of our science. And just as this account is founded on correct observation, and harmonises with sound induction, so the more rapidly will Physical Geography attain to perfection. "It is not enough for it" (in the eloquent language of M. Guyot) "coldly to *anatomise* the globe by merely taking cognisance of the

arrangement of the various parts which compose it. It must endeavour to seize those incessant mutual actions of the different portions of physical nature upon each other—of inorganic upon organised beings, upon man in particular, and upon the successive developments of human societies; in a word, studying the reciprocal action of all these forces, the perpetual play of which constitutes what may be called the Life of the Globe, it should, if I may venture to say so, take up its Physiology." Understanding it in this light, the scheme of nature becomes invested with new interest, its various portions assume new harmony and unity, and man, in his physical, social, and moral development, stands in a clearer and closer relationship to the whole.

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